Psychological Monographs

Vol. X
No. 4

September, 1909
Whole No. 43

THE

Psychological Review

EDITED BY
J. MARK BALDWIN

HOWARD C. WARREN
PRINCETON UNIVERSITY

JOHN B. WATSON
JOHNS HOPKINS UNIVERSITY

AND

CHARLES H. JUDD, UNIVERSITY OF CHICAGO (*Editor of the Psychological Monographs*)

Wellesley College Studies in Psychology

No. 1

A Study in Memorising Various Materials by the Reconstruction Method

BY

Eleanor A. McC. Gamble

Associate Professor of Psychology and Director of the Psychology Laboratory

THE REVIEW PUBLISHING COMPANY
41 NORTH QUEEN ST., LANCASTER, PA.
AND BALTIMORE, MD.

BF1
.P8

PREFACE.

The purpose of this monograph is to report and to discuss the results of a series of experiments made, with one unimportant exception, in the Psychology Laboratory of Wellesley College during the seven academic years ending with the Christmas holidays of 1908. A brief appendix outlines the history of other investigations carried on in this laboratory and published before this first volume of the Wellesley College Psychological Studies. The object of this preface is to define the writer's responsibility for the chapters of the present monograph, and at the same time distinctly to acknowledge the assistance of numerous co-workers.

As divided by their personnel, the experiments fall into four groups, namely: (1) Long series of experiments made upon the writer by advanced students; (2) shorter but parallel series of experiments made by advanced students upon one another; (3) still shorter series of experiments made by first-year students upon one another; and (4) two series of experiments made by the writer,—one upon Wellesley students and the other upon two young German women in Göttingen. By advanced students are meant students who were doing a second, third, or fourth full year of college work in psychology. Of these experimenters, only a few can be enumerated here. The names of the others are given in connection with a tabular view of the experiments at the end of the first chapter. The first-year students are by far too numerous to be listed at all, but are none the less gratefully remembered as contributors.

The students who took the largest share in the work are Miss Mary C. Smith and Miss Mabel B. Woodbury. This report embodies the results of experiments which formed the basis of theses successfully presented to the faculty of Wellesley College in partial fulfillment of the requirement for the master's degree. These theses were not prepared by their writers for publication.

The results were left in the hands of the present writer and were to be published in one paper under the three names. The writer delayed this report for the sake of working over the record in different ways and of making set after set of control-experiments. Thus, the mass of results has grown to dimensions not at first imagined. Moreover, the later work has overturned conclusions based upon the earlier experiments. Unfortunately, as the case now stands, unity and brevity require that the work of Miss Smith and Miss Woodbury should be merged with that of other contributors. The writer appropriates with especial compunction the work of Miss Smith, who not only furnished a larger mass of numerical results than any other one student has presented, but who also took part in working out the method of procedure upon which the whole investigation has hinged. Other students to whom cordial acknowledgment is due are Misses Eleanor M. Bennett, Ethel Bowman, Helen D. Cook, Maud Dewar, Sarah J. Woodward, and Helen M. Young.

The writer is responsible for the conduct of the whole investigation, served as the principal subject through almost its whole course, took the lion's share in computing and in tabulating the results, and has written this report *in toto*. She stands to the the experiments by the reconstruction method much as Professor Ebbinghaus stood to the pioneer memory-experiments published in *Ueber das Gedächtnis*. There are, however, two important differences. In the first place, the writer did not herself experiment upon herself. In the second place, the most important conclusions which may be drawn from the experiments made upon her have been confirmed by tests made upon other persons.

In serving so largely as subject, the writer had at first a purely practical and pedagogical motive. It is her duty to direct students in elementary research-work, and she is convinced that she can best direct such work by serving freely as subject. Later, as one set of experiments grew out of another, it seemed important that the subject most often employed should remain the same person. Moreover, as a matter of hard fact, the writer continued to be the only subject available for an extended and exacting investigation.

This merging of the offices of laboratory director and of subject has three obvious disadvantages. In the first place, the subject as director knows more than a subject ought to know about the purpose of the experiments and may thus be influenced by "expectation," in the technical sense. In the second place, the director as subject is certain to notice flaws in the method, as well as mistakes on the part of new experimenters, and such reflections may seriously distract attention from the task immediately in hand. In this investigation these two sources of error were not very serious, as the results will show. In the third place, as subject the director is debarred by the experimental proprieties from examining the numerical results as they come in week by week. This third disadvantage has not only been one factor in belating the report of the earlier experiments, but has also entailed, at some points, a lamentable lack of foresight in the conduct of the investigation. Over against these draw-backs is to be counted, in partial compensation, the advantage that the director as subject has an intimate knowledge of the procedure such as no mere overseer, however observant and critical, could possibly have. The greatest advantage, however, is strictly personal and practical and has no scientific value. This lies in the fact that the relation of teacher and pupil is, for the most part, merged in the mutually stimulating relationship of fellow-workers. In the pages which follow, the 'laboratory *we*' has not merely the editorial significance, but denotes a very genuine plurality.

In ending this preface, the writer wishes to express her grati-gratitude to her own instructors, Professor Edward Bradford Titchener and Herr Professor G. E. Müller, for ideals of rigid experimentation which are none the less revered because this work falls so far short of them, and desires, above all, to thank her 'chief,' Professor Mary Whiton Calkins, for constant encouragement in research and for unstinted help in the final preparation of this study for publication.

ANALYSIS.

CHAPTER I. PROBLEMS.

PAGE

Introductory remark on the historical relation of the problems..... 1

A. Genesis of first problem, viz: the occurrence and differentiation of smell-imagery..... 1

B. Growth of second and third problems out of first..... 2

Formulation of second problem, viz: the character of concrete impressions (smells and colors) in comparison with nonsense-syllables as material for memorising..... 6

C. Formulation of third problem, viz: the peculiarities of the reconstruction method as compared in particular with the method of complete memorising..... 7

Explanations of the small number of repetitions required for memorising with the reconstruction method:

I. The presence of the series-members..... 7

II. Spatial localisation..... 9

III. Multiplied tests of mastery..... 9

IV. Leisurely recall..... 9

V. Long intervals..... 10

Tabular view of experiments..... 13

CHAPTER II. MATERIAL.

A. Description of material.

I. Scents.

a. Indication of substances used..... 15

b. Manipulation..... 16

II. Colored papers..... 17

III. Nonsense syllables.

a. German normal series..... 19

b. English normal series..... 19

c. English series of haphazard formation..... 22

B. Method of series-formation in the case of smells and colors

I. Operation of chance.

a. Mechanical methods of drawing series-members..... 24

b. Limitations..... 25

II. Reasons for allowing chance to operate..... 26

CHAPTER III. METHOD.

PAGE

A. Details of the experimental procedure by the reconstruction method

I. Method of presenting series for memorising.

a. Lack of apparatus 30

b. Blindfolding in the smell-series 31

II. Method of presenting series for reconstruction.

a. Presentation of series-members in chance order 32

b. Presentation of series-members singly 32

Inference in reconstruction 32

Reproductive reinforcement in the reconstruction of visible series 33

III. The nature of a 'perfect' reconstruction.

a. The demand for objective correctness 34

b. The operation of the 'placing-rules' 34

c. The demand for certainty of correctness 36

Relative complexity of the task with the three sorts of material 37

IV. Time-intervals.

a–b. Rate of series-presentation 39

Reason for difference in rate between the smell-series and the visible series 41

Certain possible consequences of the slow rate of presentation 42

c. Interval between the presentations of the series 42

'Distributed repetitions' of thelonger series 43

d. Interval between presentation and reconstruction 43

e. Time required for reconstruction 43

f. Intervals between the learnings of different series at the same sitting 44

g and *h*. Hours of the experimental sittings 44

i. Programs for the use of different sorts of series. (*Zeitlage*).. 44

Summary of important points 45

B Treatment of the numerical results.

I. The counting of the right cases obtained on the several reconstructions 46

The two sorts of right cases 46

The massing of results 48

II. The counting of the number of repetitions necessary for correct and for perfect reconstruction 48

III. The counting of the number of series in a set correctly and perfectly reconstructed on the first attempt 48

PAGE

C. Preliminary comparison with other methods of the reconstruction method as used in these experiments.

Introductory remark on the general division of methods..... 51
I. Comparison of this method with the reconstruction method of Münsterberg and Bigham..... 51
II. Comparison of this reconstruction method with the reproduction methods.
Historical note..... 53
a. Sketch of the reproduction methods.
1. The method of complete memorising..... 54
2. The memory-span method..... 54
3. The method of right associates..... 54
4. The prompting method..... 55
5. The method of retained members..... 55
Summary of characteristics..... 55
b. Parallel features in the reconstruction method..... 56
c. Peculiarities of the reconstruction method.
1. Importance of associations between all series-members... 57
2. One complete reproduction for every complete presentation..... 57

CHAPTER IV. NUMERICAL RESULTS OF EXPERIMENTS IN MEMORISING THE SERIAL ORDER OF SMELLS AND OF COLORS.

Experiment Groups I–III.

A. Tables of results with explanation and discussion.
I. Tables I–VI..... 60
II. Explanation of tables.
a. Abbreviations..... 59
b. General arrangement..... 66
c. Details in regard to the experiments represented..... 68
III. Discussion of results.
a. The small number of repetitions required for memorising... 75
b. The mean variations..... 76
c. Comparison of the numbers of repetitions necessary for correct and for perfect reconstruction..... 77
d. The number of right sequences obtained by the principal subject on the first trial..... 77
e–i. The great effect of practice..... 77

PAGE

j–k. The small effect of series-length 80

l. The lack of correlation between the number of repetitions necessary to memorise and the number of right sequences obtained at the first trial 81

B. Discussion of results not represented in Tables I–VI.

I–III. The length of the series memorised with a single presentation. Table VII 82

IV. Breaches of the placing-rules 85

V–VI. The number of positions learned on the first presentation ... 85

General conclusion: Striking divergence of the results from those obtained by the methods of complete memorising and of the memory-span 87

CHAPTER V. THE MENTAL PROCESSES INVOLVED IN MEMORISING SERIAL ORDER.

Introductory remark on the initial possibility of explaining the results obtained with colors and smells by the concrete nature of the material 90

A. Numerical results of experiments in memorising in turn the serial order of smells, colors, and nonsense-syllables. Experiment Group IV.

I. Tables of results with explanation and discussion.

a. Tables VIII and IX 92

b. Explanation of tables 91

c. Discussion of results.

1. The approximate equality of the numbers of repetitions necessary for memorising the three sorts of series 95

2. The relative effect of practice in the three sorts of series ... 97

3. The transfer of practice in the case of the principal subject 97

4. The relatively small effect in the case of the syllables of series-length on the number of repetitions necessary to memorise 97

5. The breaking of the placing-rules in the case of the syllables 98

6. The number of sequences learned on the first presentation of syllable-series of different lengths 98

II. Discussion of results not represented in Tables VIII and IX.

a–c. The numbers of positions learned on the first presentation 99

General conclusion: Impossibility of explaining the results obtained with the smells and colors by the nature of the material 101

B. Interpretation of the numerical by the introspective results of the reconstruction method. Experiment Group V: Control experiments

Preliminary discussion of the kinds of associations involved in memorising series or serial order 102

PAGE

I. The subject's methods in memorising.
a. The character of the images representing the series-members 105
The scarcity of true olfactory imagery 110
Relative complexity of the imagery in the case of the concrete material 113
b. The character of the associations formed between the series-members.
1. The nature of the primary associations..... 115
The learning of the series-members by the principal subject 117
2. The use of auxiliary associations..... 119
c. The grouping of the series-members..... 121
d. The consciousness of practice.
Introductory summary of the analysis of practice by other writers 123
1. The experience of the principal subject.
Remark upon earlier self-training..... 124
(*a.*) Learning to group..... 125
(*b.*) Improvement in apprehension of syllables..... 125
(*c–b.*) Negative experience in regard to certain factors in less advanced practice..... 126
Permanence of representative associations..... 126
(*j.*) Elaboration of spatial associations..... 127
2. Remarks of other subjects..... 127
II. The differences experienced with the three sorts of material.
a. In the ease with which series-members are apprehended.... 129
b. In the case with which the series-members are distinguished from one another..... 130
c. In attention-value..... 133
d. In richness in associations extrinsic to the particular series
1–2. Serviceable extrinsic associations..... 136
3. Disadvantageous extrinsic associations 136
Anticipatory and retroactive inhibition in the case of the principal subject..... 138
e. In variety..... 141
f. In the dependence of the difficulty of a series on the order of the series-members 144
g. In visibility and invisibility.
1. Reproductive reinforcement in the visible series..... 146
2. The handicap of blindfolding in the smell-series..... 147
Several general conclusions..... 148

PAGE

Essential similarity of the mental processes concerned in memorising the the verbal and non-verbal material..... 149

CHAPTER VI. AN EXPERIMENTAL STUDY OF THE RECONSTRUCTION METHOD AS USED IN THESE EXPERIMENTS.

A. Account of the experiments

I. Bearing upon the stability of attention during the presentation of the series. Group VI..... 150

II. Bearing upon the explanation by presence of the links. Group VII..... 153

III. Bearing upon the explanation by spatial localisation. Group VIII..... 157

IV. Bearing upon the explanations by spatial localisation and by multiplied tests of mastery. Group IX..... 159

V. Bearing purely upon the explanation by multiplied tests. Group X..... 163

VI. Bearing upon the explanations by multiplied tests and by long intervals between presentations. Group XI..... 169

VII. Bearing upon the facility of the principal subject in learning by the method of complete memorising, and on the explanations by multiplied tests, by leisurely recall, and by long intervals. Group XII..... 172

B. Combination and interpretation of results.

I. Discussion of the small number of repetitions required for memorising by the reconstruction method.

a. The explanation by presence of the links..... 195

b. The explanations by multiplied tests of mastery and by long intervals between presentations..... 198

c. The explanation by leisurely recall..... 199

d. The explanation by slow presentation..... 199

Peculiarity of the results obtained by the method of complete memorising. Experiment Group XII..... 202

II. Explanation by the slow rate of presentation in the reconstruction method of the small importance of series-length.

a. The physiological advantage of slow presentation..... 202

Consolidation *versus* persistence..... 203

b. The advantage of slow presentation in the acquirement of technique..... 208

CHAPTER I.

PROBLEMS.

This investigation is largely concerned with the memorising of the serial order of concrete impressions; or, more explicitly, of smells and of colors. The word *concrete* is here used as the opposite to the term *verbal* and as an equivalent to the German word *anschaulich*. The question upon which most of the experiments were designed to bear is this: Do the laws of memorising concrete impressions differ from the laws which have been demonstrated for the memorising of series of nonsense-syllables?

As a matter of historical fact, the genesis of this question was accidental. The investigation grew out of an interest in gauging the development of smell-imagery. In order of time, our interest centered, first, in the occurrence, differentiation and life-likeness of true smell-images; second, in the comparison of smells and colors with nonsense-syllables as material to be memorised; and third, in comparing our method with other memory-methods. On the other hand, in order of importance, the third interest stands first and the first third. Thus, the largest concern of the investigation is neither its first concern in time nor its most important concern in reality. The interconnection of the chapters which follow will be clearer if a preliminary account is given of the fashion in which one question grew out of another.

A. Our interest in *smell-imagery* was stimulated by a remark of Professor Titchener upon its small importance in the mental life of civilized human beings. He calls attention to the fact that we often have an *illusion* of smell, and to the possibility that "with continued practice the power of imaging scents could be regained." He concludes, however, that as it is, the power is, for the most part, unemployed if not lost.[1] These

[1] *Primer of Psychology*, edition of 1898, p. 128.

statements attracted our special notice in the academic year 1898–1899, at a time when we were encountering experimental difficulties which were apparently due to the suggestibility of smells. We were then attempting with Zwaardemaker's fluid-mantle olfactometer to obtain from about forty students in a first year course in psychology certain statistical data in regard to the keenness of smell. This investigation was a failure and demonstrated chiefly the impropriety of using unpracticed observers in smell-work. One great difficulty lay in the inability of such observers to distinguish between a 'real' and an 'imaginary' smell. Of course, one encounters an exactly parallel difficulty in all work with stimuli of barely liminal intensity. In olfactometric work, however, one finds the error in an aggravated form. Whatever the explanation of this fact may be, the mere existence of such a difficulty in determining the smell-stimulus threshold proves the ready suggestibility of weak smell-images. Furthermore, *pari passu* with the statistical olfactometric tests of 1898–1899, we obtained questionary evidence, more direct if less reliable, for the occurrence of at least some smell-images in the cases of many of our observers. The interest aroused by this evidence, direct and indirect, led to continuance of the questionary-investigation, and finally, to the the experiments in memorising series of smells. In these experiments, the question of smell-imagery soon dropped to a place of secondary importance. In this report, it will be treated as a subsidiary issue, and mere questionary evidence upon the subject will not be included.

B. Our experiments in *memorising the serial order of concrete impressions* began with the use of smells. The first of the smell-experiments were made in the year 1901–1902, and were undertaken as a possible, though indirect, means of gauging the suggestibility of smells in terms of smell-images proper. Our first plan was vague; our purpose was simply, first, to study the process by which series of smells could be memorised, and, second, to compare the difficulty of memorising such series with the difficulty of memorising series of nonsense-syllables.

To explain the transfer of interest from the memorising of smells as such to the memorising of non-verbal impressions as

such, it is necessary (as will soon appear) to give a brief account of the method employed in memorising and reproducing the smell-series. The detailed description of method will be reserved for Chapter III.

To test the memory of a series of smells, one must either require the subject to name (or to describe) the smells in order or must resort to some form of the reconstruction method.[1] A really direct reproduction is non-communicable, even if it should occur unmixed with verbal images. That is to say, the subject cannot by any *fiat*, without the use of words, produce in the mind of the experimenter the smells of rose, tar, almond, or whatnot, in succession. But to require the translation of the smell-experiences into words would have vitiated the experiments in so far as they were designed to throw light upon the existence and differentiation of smell-imagery. We were, therefore, confined to the second alternative, the use of the reconstruction method.

The method of procedure, when perfected, was briefly this: The odorous materials of the series were put into small bottles of uniform size and shape. The subject was blindfolded. The bottles were handed to her in strict succession at intervals of about five seconds. When the series was finished, the bottles were so mixed together as they stood on the table that the subject could not (except by a negligible chance) take them up in the original order. The first bottle was then given her again by way of initial suggestion. She was now required, to take up, blindfold and at random, the bottles one by one, and, by the aid of smell alone, to arrange them in a row or rows on the table in exactly the order in which they were first given her. She was not allowed, during the same attempt at reproduction, to smell again any bottle after she had once smelled another. A distinction was drawn between a merely 'correct,' and a 'perfect,' that is, an 'unhesitating' reproduction. A reconstruction was not accounted perfect unless (1) no bottles had been transposed, (2) no bottles which came next to each other in the series had ever been separated by a gap, and (3) no bottles which did not come next to each other had ever been placed in contact. These

[1] On the origin and application of the term *reconstruction method*, see p. 51.

rules we commonly called 'the placing-rules,' and they will, henceforth, be referred to as such. They will be discussed in some detail in Chapter III. It should, however, be noted here that since the subjects were blindfolded and could smell but one scent at a time, all memories of sequence (such memories, for example, as that 'tar came next to rose') necessarily involved the representation, direct or symbolic, of at least one 'absent member' of the series, that is, of one member not then present to sense.

If a series was not reproduced perfectly, all the bottles were again presented to the subject in the proper order, and a second reproduction was required under the same conditions as the first. This process was repeated until a perfect reproduction was obtained.

As will readily appear, the objective or numerical results of these experiments can throw no direct light upon the problem of smell-imagery. For, in the first place, by a limitation characteristic of the reconstruction method, the subject can correctly reproduce the order of the series without really representing to himself, either directly or symbolically, the individuality of any one of its members. Memories of sequence involve the representation, the imaging, direct or indirect, of absent members, but one may conceivably reproduce the series-order without any memories of sequence. That is to say, it would be quite possible, if not easy or natural, to reproduce the series-order simply by remembering in number-words, or other number-symbols, the absolute position of the links. Let us suppose, for instance, that ginger and cloves are the fourth and seventh smells in a series, and that the cloves bottle comes first to the subject's hand and the ginger bottle second. Then, he will set the ginger bottle on the proper side of the cloves and will leave space for other scents between ginger and cloves, if he simply remembers that the 'last smell' was the seventh in the series and that 'this one' is the fourth. As a matter of fact, these mental number-tags were an exceedingly important guide to most of the subjects in arranging the smell-series.[1]

[1] We shall discuss later another exceedingly important form which memories of absolute position may take, namely, the association of the links of the series with different spatial positions.

It should be noted, however, in passing, that although the numerical results are largely equivocal as regards the question of method in memorising, yet the tabulated introspection of the subjects (see Chapter V, pages 115–119) fully bears out the natural assumption that memories of sequence coöperated with those of absolute position in the learning of the series-order.

But, in the second place, even if one memorises the order of the odors entirely by noting the sequences, and abstains entirely from counting and other methods of 'absolute placing,' this does not imply that one recalls the series, even partially, in terms of true smell-images. Let us suppose that the first seven smells of a series are, respectively, rose, tar, almond, ginger, chloroform, cinnamon, and cloves. Then one may memorise the order simply by repeating to oneself word-sequences such as 'tar, almond,' or 'cake-smell, sickly-sweet smell.' Or one may indulge in a series of mental pictures of a rose-bush, a tar-barrel, an almond-nut, a ginger-cake, an operating-room, a pink lozenge, and a phial of oil of cloves. As a matter of fact, the writer, who was the subject most often employed, has no true smell-imagery whatsoever, in spite of eleven years of practice in smell-experiments, an excellent discrimination for olfactory qualities, and a good capacity for memorising the order of the scents. In the writer's case, the smell-images are replaced primarily by color-images. The smell of rose, for example, is represented by a spot of rose-color, the smell of tar by a black spot, and the smell of almond by a pale violet tint, which is the subject's synæsthetic color for the word *almond*. These substitutes for smell-images will be more fully discussed in Chapter V. Enough has been said in this place to emphasise the very indirect bearing of the numerical results upon the problem of smell-imagery. Upon this question the self-observation of the subjects alone is crucial. The figures which represent a subject's achievements in memorising as compared with those of other subjects serve merely as a somewhat distant control upon her introspective statements in regard to her method of memorising.

Nevertheless, these numerical results of our early experiments with smell-series proved to be distinctly interesting quite

apart from the purpose with which they were originally obtained. The interest arose through a comparison of our results with those obtained by Ebbinghaus and by Müller and Schumann with nonsense-syllables as material and by the method of complete memorising. In making this comparison we were impressed with the following facts: First, in our form of memorising, a relatively small number of presentations of the series was required even at the outset and apart from the effect of practice. Second, in our form, practice had a continuous and marked effect which could not be neglected at any stage of the experiments.[1] Third, the increase of difficulty with increase of series-length was very small as compared with the increase found by Ebbinghaus.[2] These differences might conceivably be due to differences of material or to differences of method or to both. The testing of these suppositions constituted our second problem, the comparison of concrete impressions with nonsense-syllables as material for memorising, and our third problem, the comparison of the reconstruction method as used by us with other memory methods.

Experiments with smells were made according to the method described above for four successive academic years, ending with the year 1904–1905. In 1902–1903, the second year of the smell-experiments, tests were begun by the same method with colors as material, in order to discover whether or not a second kind of concrete material would show the peculiarities shown by the smells. Small squares of colored paper made up the series and were presented to the subject singly as the scent-bottles had been presented. These experiments also were continued through the year 1904–1905, but by the spring of 1904, it was fully proved that memorising the serial order of colors showed exactly the differences which were shown in memorising the order of smells when compared with the memorising of series of nonsense-syllables by the method of complete memorising. Therefore, in the year 1904–1905, experiments were made by our reconstruction method with nonsense-syllables as material in order to decide whether the differences in question were due

[1] See p. 78 below.
[2] See p. 87 below.

to the difference between concrete and verbal material or to the differences between the reconstruction method as used by us and the method of complete memorising. The syllables were printed by hand upon small cards and were presented to the subject exactly as the colors were presented. It was now proved, easily and absolutely, that nonsense-syllables, when memorised by the reconstruction method, show no crucial differences from smells and colors, and that the divergence of our results from those of Ebbinghaus and of Müller and Schumann is to be explained through the difference in method. Thus, late and by a very round-about path, we arrived at our third and most important problem, the characteristics of the reconstruction method as compared with other methods of memory-experimentation.

Chapters II, III, IV, and V all deal with the experiments bearing upon our second problem, the comparison of smells and colors with nonsense-syllables as material to be memorised. These experiments are placed first, not merely because they bulk largest in these studies as a whole, but because the third problem shaped itself out of their results and because the first problem cannot be satisfactorily considered apart from them.

C. Our *comparison of the reconstruction method with other methods of memory-experimentation* has been mainly directed toward finding out why the order of a series can be memorised by our form of the reconstruction method with a number of presentations which is relatively very small as compared with the number required to memorise the series itself by the method of complete memorising. To this question the following answers readily suggest themselves:

I. The mere reconstruction of the series-order is intrinsically far easier than the reproduction of the links themselves. This is the explanation which most readily suggests itself but it is also the least adequate. As a matter of fact, the subjects tested in this regard were found to learn the series itself fairly well in the process of learning the series-order. Detailed experimental evidence is not in place in this chapter. It is important, however, to affirm at this point the insufficiency of the first explanation, for if it were adequate, there would be no justifica-

tion whatever for comparing the reconstruction method with the method of complete memorising. It may, at least, be noted here that it is somewhat gratuitous to assert that it is very much harder to reproduce a series link by link in order, than it is, when the links are presented one by one, to reconstruct the order of the series with a perfect observance of the 'placing-rules' given on page 3. In the one case, each link, as it is reproduced by the subject, must suggest some other link; in the other, most of the links, as presented to the subject, must severally suggest either two other links or an idea of absolute position or number in the series. Let us suppose that the syllables *kex*, *lum*, *dat* and *wog* form part of a series of nonsense-syllables. Why should it be very much harder to recall these syllables bodily in succession than to remember when first *wog*, then *kex*, and then *dat* is presented, that the *dat*-card must be placed between the *kex*-card and the *wog*-card and must touch the *wog*-card but not the *kex*-card? As a matter of fact, the process of reproduction with both methods is more complicated than this simple statement and illustration indicate. For instance, in the reconstruction of series, memory is often eked out by inference. It seems best, however, to reserve further discussion until our experimental method has been described in detail, and until the actual numerical results and the introspective testimony of the subjects have been presented. The writer wishes at this point merely to insist that the difference between the results of the reconstruction method and the method of complete memorising cannot be disposed of, in easy and summary fashion, by saying that, in the one case, merely the series-order and, in the other, the series itself must be reproduced.

Of course, it is perfectly true that the reconstruction of a series implies directly only a mastery of the series-order, and does not necessarily involve an ability to reproduce the series-links. Experiments by this method are experiments only in memorising series-order and not in memorising series. This distinction will never be forgotten in the pages which follow, although in the chapters which precede the comparison of the reconstruction method with others, series will be said, for the sake of brevity, to be memorised when they are reconstructed perfectly in the technical sense.

II. Another answer to the question under discussion is as follows: Memorising by the reconstruction method is relatively easy because in the act of reconstruction the subject translates a merely temporal into a spatial order to which he particularly attends. After a certain amount of practice in the reconstruction of series, visual images of spots on the table, or tactile images of positions relative to the body, may spring up even when the series is presented for the first time and before the subject has made any attempt to rearrange it. Now we know, even from the most ancient mnemonics, that spatial associations are extremely valuable in memorising.[1]

III. A third answer is this: With the reconstruction method a series need be presented but a small number of times because after each presentation the subject tests his knowledge of the whole series and the degree and nature of his ignorance. In the method of complete memorising, on the contrary, he may read the series any number of times he chooses without attempting to reproduce it from memory, and in any attempt at reproduction, he always reads to the end of the series as soon as the first hesitation occurs.[2] Indeed, the reader may perhaps be tempted to consider that one of our presentations and reconstructions was equivalent to two presentations by the method of complete memorising. A little reflection, however, shows that this view is hasty. In the process of reconstruction, the units were indeed again presented to the subject, and through this presentation, might become more familiar, but the order, that which the subject was required to reproduce, was not repeated. In the act of reconstruction, the subjects did indeed impress the order upon themselves, in so far as they already knew it, but they also impressed upon themselves their own mistakes, so that the next presentation had not merely to foster correct impressions but also to weed up errors.

IV. Still another theory is as follows: It may be that a relatively small number of repetitions is required by our method

[1] See Cicero, *De Oratore*, ii, 86 squ.

[2] Ebbinghaus, *Ueber das Gedächtnis*, p. 34; Müller and Schumann, *Experimentelle Beiträge zur Untersuchung des Gedächtnisses*, Zeitschrift f. Psych. und Phys. der Sinnesorgane, vi, p. 84 and pp. 187–190.

because the subject is not timed and thus 'flurried' in the process of reproduction. With some subjects the emotional disturbances involved in reciting a series of syllables learned by the method of complete memorising is considerable, and is in its results akin to stage-fright.

V. Finally, a fifth answer to the question under consideration is the following: A small number of repetitions is required by our method because the series are presented with longer intervals (1) between the units and (2) between the end of one presentation of the series and the beginning of the next. As far as verbal material (including numbers) is concerned, there is adequate experimental evidence for the belief, that, at least within certain limits, the lengthening of the intervals, either between the units or between the repetitions of the same sequence, increases the amount which can be memorised in the single presentations of the series.[1] Now the intervals between our syllables and colors, which were presented approximately at the rate of three and one-half seconds to one unit, were four or five times as long as the intervals used by Müller and Schumann and almost nine times as long as the intervals employed by Ebbinghaus in the experiments described in *Ueber das Gedächtnis*.[2] Moreover, in our case both the lengthening of the single presentations and the interpolation of the attempts at reconstruction between presentations lengthened the intervals between the repetitions of the same sequences.

To discuss in full the nature of the advantage given to the learner by long intervals would lead us into a thicket of evidence and argument which it is better to avoid in an introductory chapter. However, one consequence of making the intervals between the units very long is perfectly obvious: the subject has ample time to interpolate connecting links. For instance, in our own experiments, before a third link of the series was presented, *gur jal* would have full time to suggest currant jelly, scarlet and black to suggest the 'devil's mourn-

[1] See p. 43, note 1, and p. 193, note 1. The statement in the text must not be understood to mean that a slow presentation accomplishes more in proportion to the time expended than a more rapid one.

[2] Müller and Schumann, *op. cit.*, pp. 91 and 97; Ebbinghaus, *op. cit.*, p. 38.

ing,' and the smells of wintergreen and pine-needles to suggest a search for arbutus. In the first year of the experiments, the subjects were charged not to use such artificial links but to 'memorise mechanically.' The meaning of the regulation was made perfectly clear to them, yet it proved utterly impossible to enforce it. The smells could not be presented faster than at the rate of four seconds to each unit. The colors and syllables were also presented without apparatus[1] and slowly that the conditions might be comparable. Yet when the links were presented thus slowly, extraneous associations were certain to obtrude themselves. The conscientious subject could only struggle against these associations much as the mediæval recluse struggled in vain against the verbal images which he regarded as Satanic suggestions. This combat distracted attention from the series, and, because only in part successful, prevented uniformity in the experimental conditions not only as regards different subjects but as regards the same subject at different times. Therefore, one year after the smell-experiments and one month after the color-experiments were begun, all restrictions upon the subjects' *mental* operations were abolished, and they were allowed to memorise in any fashion which the external experimental conditions permitted.

Other consequences of slow presentation will be discussed when the experimental results are presented. One is the possibility that during the intervals the subjects were able to make a mental review of foregoing sequences. Another is the relatively accurate apprehension of the material. A third is emotional composure on the part of the subject during the presentations, composure coupled, perhaps, with a rather low grade of attention. It is not profitable to discuss these circumstances apart from the details of method and from the experimental and introspective data.

For the sake of brevity, the foregoing suppositions will be called the explanations (I) *by presence of the links*, (II) *by spatial localization*, (III) *by multiplied tests of mastery*, (IV) *by leisurely recall* and (V) *by long intervals*. The fifth explanation is twofold, including both the explanation by slow presen-

[1] See p. 130.

tation and the explanation by long intervals between presentations, that is, between the end of one presentation of the series and the beginning of the next. In the spring of 1904–1905, we began to test these suppositions experimentally, and have made tests of different sorts at intervals until the Christmas holidays of 1908. As the results reported in Chapter VI will show, all five suppositions contain a certain amount of truth,—the fourth and fifth, most, and the first, least.

Before the reader enters upon the description of the materials and method used in the reconstruction experiments, it should be stated clearly—it cannot be stated too clearly or emphatically—that we have to describe only a large mass of rough experiments—some of them shockingly rough. The cause of this roughness was twofold. In the first place, the smell-experiments were the nucleus of the whole investigation, and most unfortunately all work with smells is at present crude. The experiments with colors and nonsense-syllables were made primarily for the sake of comparison with the smell-experiments, and in them, greater precision of method, though possible, seemed out of place. In the second place, the *personnel* of the experiments was large, varied, and in part unpracticed. The conditions of the experiments differ *toto coelo* from the conditions of the precise experiments made by Professor G. E. Müller and his co-workers. Nevertheless, the writer believes that the results have a certain value upon account of their large mass and even just upon account of the varying conditions under which they were obtained. It is true that a chain, however long, is 'no stronger than the weakest of its links,' but it is also true that very stout rope may be composed of fragile fibers of hemp *which run parallel to one another.*

To this chapter is appended for the reader's convenience a tabular view of the experiments:[1]

[1] The advanced-student experimenters not mentioned in the preface were Misses M. G. Alexander, M. Clark, F. V. Cook, E. B. Doak, E. Foster, C. B. Green, J. A. Hewitt, M. C. Kasson, A. J. Klingenhagen, L. Loos, A. G. Lyon, A. E. Moore, E. D. Newton, J. Risdon, E. C. Taylor, J. P. Wilson, and L. Wilson.

GROUP I. 1901–1902 and 1902–1903.

Initial object: To study the development of smell-imagery.

Method: Reconstruction.

Outcome: Data as to the effect of practice in memorising the serial order of smells.

GROUP II. 1903–1904.

Object: To study the effect of series-length in memorising the serial order of smells.

Method: Reconstruction.

GROUP III. 1902–1903 and 1903–1904.

Object: To study the effect of practice and of series-length in memorising the serial order of colors.

Method: Reconstruction.

GROUP IV. 1904–1905 and 1905–1906.

Object: To study the relative difficulty of memorising the serial order of smells, colors, and nonsense-syllables.

Method: Reconstruction.

GROUP V. 1903–1904, 1904–1905, 1905–1906, and 1908–1909.

Object: To check the memorising-methods of the subjects—chiefly, of G.—in the reconstruction-experiments.

Methods and Materials: Miscellaneous.

GROUP VI. 1902–1903.

Object: To study the effect of distraction in memorising the serial order of smells.

Method: Reconstruction.

Value: Bearing upon the explanation by long intervals.

GROUP VII. 1907–1908.

Object: To test the explanation by presence of the links.

Methods: Reconstruction and a modified form of the method of retained members.

Material: Nonsense-syllables, normal series.

Group VIII. 1907–1908.

Object: To test the explanation by spatial localisation.

Methods: Reconstruction and a modified form of the method of right associates.

Materials: Smells and nonsense-syllables, normal series.

GROUP IX. Spring of 1907.

Object: To test the explanations by spatial localisation, by multiplied tests, and by presence of the links.

Methods: Reconstruction and a modified form of the prompting-method.

Material: Nonsense-syllables, German normal series.

GROUP X. 1907–1908.

Object: To test the explanation by multiplied tests.

Method: Modified form of the method of retained members.

Material: Nonsense-syllables, English normal series.

GROUP XI. 1908–1909.

Object: To test the explanations by multiplied tests of mastery and by long intervals between presentations.

Materials: Colors.

GROUP XII. 1905–1906 and 1907–1908.

Object: To test the explanations by multiplied tests, by slow presentation, and by leisurely recall.

Method: Complete memorising with and without prompting.

Material in Subgroups 1 and 2: Nonsense-syllables, roughly constructed series.

Material in Subgroups 3 and 4: Nonsense-syllables, normal series.

CHAPTER II.

MATERIALS.

A. Description of Materials.

I. Scents.[1]

The list of scents actually in use in these experiments at any one time numbered at its longest 129. In the first year of the reconstruction-method experiments, we had 102 scents in use; in the next three years, 129; in the last two years of the experiments we had 135 available scents, but have confined ourselves to a range of about 83, a range which includes no very weak smells, no approximate duplicates, and no solids. Of the 129 smells on the longest working-list, 45 were essential oils, such as cassia, myrtle, rose, parsley, and garlic; 25 were artificial perfumes, such as 'lilac' and 'honeysuckle,' of formulæ unknown to the writer; 7 were flavoring extracts, such as pineapple and celery; 36 were common articles of the drug-trade and grocery-trade, such as tincture of rhubarb and chloroform, molasses and peanut butter; 10 were rarer chemical-laboratory products of known formulæ, such as lactic acid and pyridin; and the remaining 6 were civet, ambergris, and natural musk (in tincture), sour milk, water from decaying flowers, and alcohol which had been used for preserving potato-beetles.[2] According to Zwaardemaker's classification, 8 of the 129 smells were ethereal, 57 aromatic, 32 fragrant, 5 ambrosiac,

[1] The word scent is used throughout as a synonym for odorous material or smell-*stimulus*.

[2] A complete list of smells will be furnished to anyone who may wish to repeat the experiments. The artificial perfumes were nearly all either Palmer's, or 'De Laire specialties' (trade name of a large variety of concentrated artificia perfumes) obtained from the firm of Dodge and Olcott, 86–88 Williams Street New York. Most of the flavoring extracts were obtained from Joseph Burnett and Company of Boston. All the essential oils and all the rarer chemicals not included among the perfumes were obtained from the Theodore Metcalf Company of Boston.

11 alliaceous, 8 empyreumatic, 5 hircine, 2 virulent, and 1 nauseating.[1]

The scents were manipulated as follows: All were introduced into bottles which bear the trade-name of 'half-ounce squat Caswell's.' These bottles are square and therefore not easily upset, have rounded corners, and weigh about 50 grams each. The bases measure about one inch square. The stoppers are of glass and have a disk-shaped top which is easy to grasp. All liquid scents and all solids likely to rattle were dropped upon absorbent cotton which had *already been put* into the bottles.[2] Upon the bottles were pasted small labels bearing the numbers of the smells according to an alphabetical list or key. For experiments in which the subjects were not to be blindfolded, the cotton was colored, with Diamond dye, as dark a blue as possible in order that differences in the color of the liquids might not appear. In these experiments only fluid scents were used, and the labels were pasted on the bottom of the bottles. For the sake of brevity all records were kept in terms of the bottle-numbers.

We used as few solutions as possible because we wished to have for our series as many relatively discrete smells as possible. To use many alcoholic or paraffin solutions in such series is comparable to throwing a faint reddish or greenish light upon many of the paper-squares in a color-series. We considered the

[1] The fullest statement of Zwaardemaker's classification is found in his *Physiologie des Geruches*, Leipzig, 1895, pp. 233–235. It will be remembered that the framework of this classification is, in the main, that of Linnæus.

Anyone who attempts to 'bottle' as many scents as possible must be impressed with the very great qualitative differentiation of the agreeable smells and the very limited variety of disagreeable ones. Excellent additions to the list of smells used in these experiments are cadaverin (pentamethylene diamine) and scatol (β-methyl indole). The first is 'hircine'; the second, 'nauseating.' The word *nauseating* is, of course, used in a technical sense. Pyridin, which, with one exception, is the most disagreeable smell in the whole collection, belongs technically in the virulent class. (Zwaademaker has retracted its assignment to the empyreumatic class.)

[2] When a multitude of scents is much handled it is necessary to avoid cork stoppers, which are both brittle and absorbent, and to avoid the presence of free liquid in the bottles. At best, such experimental material requires constant examination and care which it would be tedious to detail here. It is, of course, entirely unsuited to quantitative work.

highest possible degree of discreteness among the smells as more desirable than such rough uniformity of intensity as we might have secured by solution and dilution. The intensity of a smell in any particular series depends not merely upon the concentration of the scent, but also, among other circumstances, both upon the quality and the fatigue-value of the scent which immediately precedes it. Therefore, within certain limits inequalities of intensity are unavoidable.[1]

Without the use of a solvent, the intensity and the pungency of very volatile scents can be reduced by the simple expedient of leaving the cork out of the experiment-bottle for a short time. We used this method with pyridin and bleaching-powder. Solutions, however, cannot be altogether avoided. Very pungent oils, such as garlic, can be used satisfactorily in solution only. Certain substances, such as coumarin, must be diluted because they have the paradoxical property of giving a weak odor at a high concentration. Others, such as the scents of some of the flavoring extracts, can be conveniently obtained only in the form of alcoholic tinctures. But fortunately the odor of pure alcohol in a tincture is almost negligible in our method of presenting the scents, since the alcohol evaporates from the cotton very quickly and leaves behind a large quantity of the scent which has been dissolved in it.

II. Colors.

The color-stimuli used in the experiments consisted of two-inch squares cut from the Milton Bradley kindergarten-papers.[2]

[1] Moreover, the intensity of the smells could not be made uniform by 'levelling up,' because the intensity of the weak smells could not be increased, nor by 'levelling down,' because if uniformity had been secured by weakening the stronger smells, many of the odors would have been too hard to distinguish from one another.

[2] These papers are manufactured by the Milton Bradley Company in Springfield, Mass., U. S. A. All the papers represented in the sample book were used by us with the exception of the engine-colored papers. In spite of the defect to be noted in the text, the Milton Bradley papers are extremely useful in elementary color-work on account of their variety of color, dead-finish, toughness, and cheapness. For a full description of the papers, see Milton Bradley's *Elementary Color*, published by the Milton Bradley Company.

There were 136 different colors and 'neutral colors' in use. In detail, these colors were as follows:

a. Ninety colors of the 'pure-spectrum scales,' comprising:

1. A saturated spectral red, orange, yellow, green, blue, and violet, designed to imitate the 'true' or 'pure' sun-spectrum colors as nearly as this imitation can be secured by pigments spread upon paper.

2. Two saturated colors intermediate between each two links in this series and between violet and red.

3. Two tints and two shades of each of these eighteen spectral colors.

b. Thirty-six colors of the 'broken-spectrum scales' (grayish).

c. Six colored grays.

d. Four neutral colors, namely, white, black, and a lighter and a darker neutral gray.

The tints and shades are designed to be proportional in brightness to the spectral colors to which they correspond. Thus, for example, the paler tint of the pure yellow is a very pale gold and the darker shade of pure yellow almost as bright as the spectral red, whereas the paler tint of the pure red is so deep a pink as scarcely to merit the name. (The set includes no good pale rose-pink.)

The Milton Bradley color scales have the defect that the series of hues is more finely graduated over exactly that portion of the scale of hues where our color discrimination is poorer. For instance, in the pure-spectral scales we have, in passing from blue to yellow through red, eleven intermediate steps, whereas in passing from yellow back to blue through green, we have only five. As a result of this disproportion, we have a mass of browns, pinks, plum-colors, and lilacs which are, of course, easy enough to discriminate when seen side by side, but which are sometimes very hard to identify correctly when seen one by one.

In the experimental records, the colors were denoted by a convenient set of symbols suggested by the manufacturers.

III. Nonsense-Syllables.

The series of nonsense-syllables used in the experiments were of three sorts, which the writer will call for brevity (*a*) the Ger-

man normal series, (*b*) the English normal series, and (*c*) the hit-or-miss series. The German normal series were made for German subjects and pronounced by German rules; the English normal series were made for American subjects and pronounced after the analogy of English words.

a. The German normal series it is not necessary to describe. They were made in Prof. G. E. Müller's laboratory in Göttingen in accordance with the rules given in such great detail by Professors Müller and Schumann.[1] The adjective *normal* is borrowed from them.

b. The English normal series were made in as exact imitation of the German normal series as the peculiarities of the English language make advisable. The series, like the normal series of Müller and Schumann, were of the lengths twelve and eighteen. In English there are twenty-one consonants and digraphs available as initials, viz: *b*, *d*, *f*, *g*, *h*, *j*, *l*, *m*, *n*, *p*, *r*, *s*, *t*, *v*, *w*, *y*, *z*, *ch*, *sh*, and *th*. In German there are but sixteen (or seventeen, including *sch* which was finally excluded by Müller and Schumann). In English, there are nineteen available as final consonants, viz: *b*, *d*, *f*, *g*, *j*, *k*, *l*, *m*, *n*, *p*, *r*, *s*, *t*, *v*, *x*, *z*, *ch*, *sh*, and *th*. In German, there are but twelve. Thus, in English a normal series of eighteen syllables can be made without any duplication of either initial or final consonant sound, whereas in a German series of eighteen, two of the initial and six of the final consonants which occur in the first twelve syllables must be repeated in the last six.

But although in the matter of consonants the advantage is with the English, in the matter of vowels it is with the German. Each German vowel and diphthong has a single proper sound (if one disregards certain very slight quantitative differences); in English most vowels and diphthongs have several. If, however, syllables cannot be translated readily from visual into auditory and from auditory into visual terms, the most undesirable complications are likely to arise in experiments upon subjects of different image-types. We aimed, therefore,

[1] Müller and Schumann, *op. cit.*, pp. 99-106. The same series were used by the writer with Professor Müller as subject in a group of experiments which does not belong among these studies.

at excluding both from the normal and from the hit-or-miss series, all syllables over whose pronunciation, or over whose spelling if presented to the ear, an educated person would hesitate. We were also unwilling to use diacritical marks. At once to avoid the use of diacritical marks, and to secure a sufficient range of vowel sounds, we adopted, in both classes of English series, the expedient of indicating the long sounds of the vowels by affixing to the final consonant the silent *e*. No educated person to whom English is the mother-tongue can hesitate long as to the difference in pronunciation of *bipe* and *bip*, *gobe* and *gob*. To correspond with the twelve vowels and diphthongs of the German normal series (which are *a*, *aa*, *ä*, *e*, *i*, *o*, *ö*, *u*, *ü*, *au*, *ei*, and *eu*), we selected for our own normal series the long and the short English sounds of *a*, *e*, *i*, *o*, *u*, and the diphthongs *ou* (to be pronounced as in *foul*) and *oi* (to be pronounced as in *boil*). A specimen-series of eighteen members runs as follows: *jil*, *nume*, *bike*, *thene*, *gour*, *pev*, *foig*, *chuch*, *rap*, *shade*, *yoje*, *sosh*, *vif*, *tabe*, *hoiz*, *wat*, *keth*, *dux*.

In these series every combination of letters is strictly to be given its normal English sound. For example, *ch* is not to be pronounced either in French or in German fashion; the syllable *chuch* has the initial and final consonant sounds of *church* and rhymes with *Dutch*. A *t* may well be inserted before the final *ch* if the series are to be presented to the eye of untrained subjects. The long *a* is pronounced as in *babe*; the short *a* as in *cat*. The Italian *a* was excluded, because it can be indicated only by a diacritical mark and because it approximates with confusing closeness to the short sound of *o*.

We imitated the method of Müller and Schumann in providing three sets of small cards,[1] bearing severally the three sets of syllable-elements (initial consonants, vowels and diphthongs, and final consonants), in making the syllables by drawing the elements separately after shuffling, and in entering every syllable thus formed in a chart, so that we might not inadvertently use the same syllable again within a given length of time.[2] In

[1] It saves trouble to have the sets of cards of three different colors since individual cards are likely to slip into the wrong boxes or packs.

[2] Müller and Schumann, *op. cit.*, pp. 101–104.

making the series we observed two different sets of rules, namely, (1) the general rules of Müller and Schumann, and (2) certain rules necessitated by the peculiarities of the English language.

1. The Müller and Schumann rules are these:[1]

(*a.*) *In a series of twelve no initial consonant, no vowe or diphthong, and no final consonant may be repeated.* The carrying out of this rule is insured mechanically by not returning any card to its pack till the series is complete. The same rule applies to the last six syllables of a series of eighteen taken by themselves, but in these syllables six of the vowels and diphthongs of the first twelve syllables must be repeated. The vowels of the twelfth and thirteenth syllables may not be the same.

(*b.*) *No syllable may begin with the consonant with which the last syllable ended.*

(*c.*) *No syllable may end with the consonant with which the last syllable began, if the two syllables in question belong to the same foot.* We extended this rule by omitting the conditional clause. The Müller and Schumann series were read either in trochaic or iambic rhythm. Our series were not always read rhythmically.

(*d.*) *No two successive syllables may together make a word or phrase.* For example, in the German the sequences *weib—lich* and *gib—mir*, and in the English the sequences *par—don* and *yes—mam* would be ruled out. It is a mistake to suppose that all German words were ruled out from the Ebbinghaus series and from the Müller normal series; *they were not.* Because they were not, we refrained from excluding English words from our normal series, except in the cases covered by the rule just given. To include words in English series may be a mistake. The language is incomparably richer than the German in monosyllables. In a set of 30 German normal series of 18 members each, with no syllable duplicated, the writer can find only 15 German words (2.8 per cent of 540), including dialect words and all verb-forms. In a similar set of English series, there are 86 combinations of letters which spell English words or common slang-words properly, and 59 more which spell them phoneti-

[1] *Op. cit.*, p. 106 (Summary).

cally, 145 in all (26.8 per cent). The including of so many words is, of course, a circumstance which tends to make the English series easier than the German. On the other hand, no devices seem to make the reading and spelling of English nonsense-syllables a simple matter for all American college students. Some of them will call *tut toot* to the end of the chapter.[1]

2. The rules necessitated by the peculiarities of the English language are these :

(*a.*) *e and i may not be used after the initial g*, since they normally give it the sound of *j* (as in *gem* and *gin*).

(*b.*) *The silent e may not be added to the final g or s*,[2] since it normally gives them the sounds of *j* and *z* respectively (as in *oblige* and *surprise*).

(*c.*) *R may not be used after short e, i*, or *o*, since *er* is in sound indistinguishable from *ur*, *ir* from *ere*, and *or* from *ore*.

(*d.*) *The silent e may not be affixed to any digraph or to x*, since the resulting syllables look so uncouth as especially to annoy the subjects.

(*e.*) No syllable may stand which has the spelling of an English word not pronounced phonetically (for instance, *dove*).

c. The hit-or-miss series differed from our English normal series in the following respects:

1. The syllables were not constructed by drawing the syllable-elements separately, but by the systematic combination of the consonants and digraphs listed above, with the addition of *qu*, and the ten long and short vowels. The vowel, of course, stood between the consonants. No diphthongs were used.[3]

2. The series were formed by drawing small cards, on which the syllables were written, out of a large box which contained the whole stock. The order in which they came out determined

[1] The modern method of teaching children in the American schools to read, the so-called 'word-method,' is probably responsible for the scanty knowledge of English phonetics in the rising generation.

[2] After the long vowels and before the silent *e*, we now replace *s* by *c* but we did not do so in the series used in these experiments.

[3] The hit-or-miss series were used in the earlier and rougher experiments. When we made the normal series used in these experiments, we abandoned the use of *qu* but are now using it again. *Wh* sounds too much like *w* to be a safe initial.

the order in which they stood in the series. Rhymes, alliterations, and combinations which constituted words were not ruled out.

3. The same syllable might appear on successive days. Since, however, all the series for each experimental sitting were ordinarily drawn out at one time, the same syllable almost never appeared twice on the same day.

4. English words, and common slang words, such as *yep* or *bike*, and nick-names, such as *Tom*, were thrown out in making the syllables. So were all combinations of letters which spelled words phonetically. Foreign words, however familiar, were not thrown out. The following series of syllables, in which those thrown out are italicised, illustrates our principles of formation and rejection: bab, *babe*, beb, bebe, *bib*, bibe, *bob*, bobe, *bub*, bube, *bad*, *bade*, *bed*, *bede*, *bid*, *bide*, bod, bode, *bud*, bude.

For our hit-or-miss series, we had a stock of about 1400 syllables. In the German normal series 2304 different syllables are possible. Müller and Schumann, however, excluded from the list 94 syllables which were especially hard to pronounce. In our English normal series, 4033 different syllables can be made out of the elements enumerated above under the first four rules peculiar to these series. Some of these syllables, however, are thrown out under the fifth rule (*e*).

For the experiments by the reconstruction method, the syllables were written or printed by hand, as legibly and uniformly as possible, with black ink lengthwise upon white cards measuring 1 x 2½ inches.

B. Method of Series-Formation in the Case of Smells and of Colors.

This section contains (I) a statement of the degree to which chance ruled in the formation of the smell- and color-series, and (II) an explanation of the fact that we did not attempt, by any more elaborate set of rules, to make up series of smells and colors which, apart from length, should be uniform in difficulty. The method by which the series of nonsense-

syllables were formed has already been fully described. It will be well, however, to add here a few words of excuse for using the roughly constructed hit-or-miss series at all. These series were used only in the experiments which had to do with the comparison of smells, colors, and nonsense-syllables, and in certain other very rough experiments. For reasons soon to be explained, the smell- and color-series were themselves of necessity constructed roughly. In extremely rough experiments, it seems hardly worth while to use series in whose making a very considerable amount of labor is involved.[1]

I. In explaining the degree to which chance determined the membership of the several smell- and color-series, it will be well to state separately (*a*) the mechanical methods by which the series-members were drawn and (*b*) the rules which were made slightly to limit the operation of chance.

a. 1. The color-squares were drawn, after shuffling, like cards out of a pack. The order in which they were drawn determined their order in the series. Each experimenter had several duplicate sets of color-squares expressly in order that several series, all drawn by chance out of the same total number of colors, might be prepared beforehand for the same experimental sitting. Thus, any color in any given series was as likely as any other color to appear in the very next series. (This statement does not apply to all the small groups of control-experiments.)

2. In most of the smell-experiments, the bottles were taken up in fairly random fashion, as they stood in the order of their numbers upon two low shelves. Thus, they were, so to speak, drawn without being shuffled. In the experiments of Group

[1] The writer cannot in an hour, even after considerable practice, make in either German or English, more than five or six normal series of twelve members each and enter each syllable both in the series-book and in the chart. In some of our experiments the series contained 41 and 81 members. Such series can be made relatively uniform by putting several normal series of twelve together, end to end, and if the delicacy of the experiment requires it, these long series can be still farther improved by applying to the component series the Müller and Schumann rules for 'verschärfter normal' (supernormal) series. (*Op. cit.* p. 104.) This last measure, if applied to a series of 81 members, would involve a labor of two or three hours.

V, the bottles were mixed together and drawn as they stood in a mass on the table. It would obviously have secured a more random selection if they had always been drawn in this way.[1] It should be noted, however, that only two out of the many experimenters had the key to the bottle-numbers. This key was purposely withheld by the director in order to minimise the deliberate avoidance and selection of particular smells. The order in which the bottles were drawn did *not* determine the series-order; on the contrary, the bottles selected usually sustained some extra shuffling. The bottles were *not* returned to the shelves until the end of the experimental sitting. Thus, whereas any color in any series was as likely as any other out of the 136 to appear in the very next series, no smell appeared, unless by accident, twice at the same sitting, although any smell might appear on successive days. The reason for this inconsistency of procedure will be stated in the next sub-section (*B*, II).

b. The operation of chance was limited as follows:

1. In the earlier color-experiments, those of the first year, no color might stand in the same series 'with any of its next neighbors in the color-pyramid.'[2] Thus the pure-spectral 'true' red might not be combined with its own darker tint or lighter shade, or with the pure spectral orange-red or violet-red, or with the broken-spectral 'true' red. At the end of the first year this rule was given up because it restricted too narrowly both the length and the differentiation of the series. Afterwards, the color-series, like the hit-or-miss series of nonsense-syllables, were drawn altogether at random.

2. In the smell experiments, (1) two extremely similar odors, such as cassia and cinnamon, or eucalyptus and rosemary,

[1] The fact that the bottles were for the most part drawn as they stood in rows in a given order was simply a matter of laboratory exigency. The scents required constant care and frequent renewal, and were also often in use for other purposes than the memory-experiments. Therefore, every person who had used the bottles was required to rearrange them upon the shelves in the order of their numbers so that any given bottle might be located at a moment's notice.

[2] The color-pyramid of Titchener. For this pyramid in its improved form, see Ebbinghaus, *Grundzüge der Psychologie*, 1905, p.199, and of Titchener, *Experimental Psychology, Students' Manual, Qualitative*, p. 3.

and (2) two extremely weak scents, such as nux vomica and our solution of heliotropin, might not be put into the same series. The lists of smells and of pairs of smells which came under these rules were, like the smell-list itself, worked out somewhat gradually. They were not fully in force in the experiments of Group I. To assist the experimenters in carrying out the rules, bits of red and of green paper were pasted to the bottles. Green labels were signals that the smells were weak; red labels bore the numbers of the bottles which might not be introduced into the same series with the ones thus marked. Of course, this device was not used when the subject was not to be blindfolded. In this case, very weak smells and approximate duplicates were excluded from the material.

II. The last sub-section has dealt mainly with the circumstances which interfere with the perfect working of chance in the formation of the smell- and the color-series. It is now necessary to explain why the formation of these series was left to chance so largely as it was. That there must have been considerable variation in difficulty from series to series of the same length is obvious. This variation was especially great in the case of the shorter series. The larger the fraction of the total number of smells and of colors which was included in every series of any given length, the more nearly equal in the long run the difficulty of the series in this group must be. The longest possible series would be identical as regards their members, and would differ only in the order in which these numbers might be arranged.

The formation of the smell- and color-series was left to chance for the following reasons:

a. With so limited a range of material, series of approximately equal difficulty cannot be sufficiently differentiated. The scheme of formation rapidly becomes obvious to the subject who anticipates members of such and such groups and compares their position from series to series. He reflects, for example, 'The bright green I had last time stood in such a place, and the pink in such another and the gray in such another; this green stands here and this pink there,' and so on. The shorter the series, the more obvious the scheme of formation. The

longer the series, the more nearly equal the difficulty even if left to chance.

b. In the case of the smells, the construction of series which are more than roughly equal in difficulty is impossible. The difficulty of memorising two series of smells depends upon at least three factors exclusive of length, of the differentiation of the odor-qualities and of the order in which the smells stand in the series. These factors vary independently, both of one another and of the differentiation of the smells, so that a selection of smells which satisfies a rule based upon one sort of difference may break a number of other rules based upon other sorts of difference. Moreover, all three factors depend upon such variable conditions that an exact control of them is impossible. These factors will be enumerated here but not discussed. They are (1) the ease with which the several smells are identified or apprehended (their *Geläufigkeit*); (2) their strikingness, that is, the degree to which they catch the subject's attention (their *Eindringlichkeit*); and (3) their richness in earlier associations which in the process of reproduction may act either in the way of facilitation or of inhibition. The same three variants appear in the case of the colors and even in that of the nonsense-syllables, but in a much less marked fashion.

c. The reconstruction method is itself so rough that great refinement in series construction is a misapplication of pains. It seems distinctly preferable to use a larger number of roughly constructed series than to use a smaller number of laboriously constructed series.

d. A considerable number of the series employed were very long. Many exceeded thirty in length, and some consisted of 61 and some of 81 members. The longer series are, the greater is the labor necessary to making them even roughly equal in difficulty by any system of rules.

Since in most of the experimental groups we used large numbers of series, we have reasonable ground for hoping that differences in difficulty between the series in those groups balance and cancel by the ordinary law of chance. Large mean variations in the results are, of course, to be expected. The ques-

tion as to which of the three sorts of series is most homogeneous is reserved for Chapter V.

In this chapter, two points only remain to be explained. The first is the fact that we left the intervals between the appearance of the same unit in the different series so largely to chance, merely providing that in the case of the smells, the same unit should not appear twice on the same day. The second is the fact that we did make this last provision in the case of the smells and did not make it in the case of the colors.

The first fact is to be explained as follows: Since there were never more than 136 colors and 129 smells in use, the same unit had to do duty over and over again. But when the same unit is employed repeatedly its whole fringe of accidental associations wears off. Smells and colors soon become like numerals and letters as material to be memorised. It is very easy to learn for the moment a series of numerals, but it is not easy to remember the position of the same numeral in different series. Each new series seems to sweep away the last. Let the reader, in order to realise how his myriads of accidental associations with the numerals inhibit one another, try to recall when and where he *last* saw the figure 9. In our first experiments with smells and colors, it seemed to make little appreciable difference whether the same smell or color occurred on two successive days or not. Therefore, it did not seem worth while to burden ourselves with any elaborate scheme of rotation.[1] The writer does not mean to say that the associations which the individual smells and colors acquired, in the course of the experiments, did not tend to inhibit the formation of new associations, but only that these tendencies are about the same for any smell which the experimenter can select on any given day, whether it has appeared on the day before or not.

The case of the nonsense-syllables is very different from that of the smells and colors. Even for the hit-or-miss series, there

[1] As a matter of fact, the director could never have secured the correct carrying out of such a scheme by all of the student-experimenters and believes that a 'compensating program' half carried out is much less desirable than the free operation of chance. Moreover, the director, who would have had to teach the experimenters how to work out such a program, was herself subject-in-chief!

were more than ten times as many syllables available as there were smells and colors. Since, however, we had no rule to prevent the appearance of the same smell or color on successive days, it seemed better to us in making the series of syllables to be compared with the series of smells and colors to permit syllables to recur on the second day as often as chance would allow them to do so. In this decision we were probably wrong. Just because a given syllable occurs so seldom upon two successive days, the subject is likely to attend especially to any syllable which does thus recur.

The explanation of the second fact, that is, our inconsistency in the case of the smells and colors, is this: In everything which had to do with the formation of these series we proceeded upon the theory that if chance were to operate at all, the more freely it was left to operate the better. Yet on account of the always imminent danger that the subject's sense-organ would be exhausted, it did not seem best to allow the smell-series given at any one sitting to be even in part the same. Furthermore, smells and colors differ in the amount of their individuality. The subject is likely to notice the repetition of any strong, familiar, or unpleasant smell and to compare its place in the two series. On the other hand, the repetition of most of the colors remains almost, if not quite, unnoticed. Smells have an individuality of their own, whereas many of the colors are identified simply as members of scales. Of course, this is by no means true of all of them. White, black, and some of the saturated pure-spectrum colors—notably, red-orange—make landmarks in every series in which they appear. The statement is valid, however, for the two kinds of material at large.

CHAPTER III.

METHOD.

This chapter does not contain a complete account of all the methods used in this investigation. Its purpose is simply, on the one hand, to describe our normal procedure by the reconstruction method, and on the other, to point out the *prima facie* resemblances and differences between this method and the other methods thus far elaborated for the study of memory. The sixth chapter will give an account of the experimental study to which we have submitted the reconstruction method; this third chapter contains merely a preliminary survey of the method in its relations to others.

A. Details of the Experimental Procedure by the Reconstruction Method.

A cursory outline has already been given (page 3) of the method used in the smell-experiments. As stated (page 6), the method employed in the color-experiments, and in the reconstruction-experiments with syllables was exactly analogous. It is not necessary to repeat in detail the description given. This section contains a more detailed consideration of the following points: (I) the manner in which the series were presented for memorising; (II) the manner in which the units were presented for the reconstruction of the series; (III) the requirements which the subjects were obliged to meet in order to reconstruct the series perfectly in the technical sense; and (IV) the length and regularity of the various time-intervals.

I. As regards the manner of presentation, it should be especially noted (*a*) that the series were presented without the use of apparatus, and (*b*) that in the smell-experiments the subjects were (normally) blindfolded.

a. No apparatus *could be* used in the presentation of the smell-series; therefore, no apparatus *was* used in the presenta-

tion of the colors and syllables. Minor details which should be mentioned are as follows:

1. In the presentation of the smell-series, the experimenter handed the bottles to the subject who was allowed herself to take out and put back the stoppers. In presenting the colors and the syllables, the experimenter laid the paper-squares and cards in the center of a small table. With the principal subject, to whom spatial associations became highly important, it was necessary always to use the same table.

This table was 24 inches square. The other tables in use in the color- and syllable-experiments measured 19 x 29 inches. The shorter diameter lay between subject and experimenter. All the tables were covered with black cloth. The size of the tables is relevant to the rate at which the series were given; the uniformity of surface eliminated all avoidable spatial associations (orientation by the graining of the wood and the like).

2. In order that no shadows might fall upon the colors, the experiments with them were made under certain skylights which are available in our laboratory.

3. The subjects were neither required nor forbidden to name aloud the smells and colors or (normally) to read aloud the syllables.

b. The blindfolding in the smell experiments was done with a soft light-weight bandage of black silk or cheese-cloth. The blindfolding was practiced in order to make sure that the smell-series were really and purely smell-series, or, in other words, that no visible peculiarities might help to differentiate the bottles. When the work was begun, no very feasible method of making the bottles uniform in appearance occurred to the experimenters. Moreover, it was thought important that the sensations aroused peripherally by the series should be purely olfactory and tactile, for it is at least possible that the occurrence of smell-images might be facilitated by the elimination of visual percepts and the extra attention concentrated upon the smells by this narrowing of attention. After the interest in smell-imagery lapsed, the blindfolding was continued from one set of experimenters to another, in order that the conditions in this important particular might be the same. The degree of difficulty which the blind-

folding introduced into the process of rearrangement will be discussed later upon the basis of control-experiments.

II. In respect to the manner in which the units were presented to the subjects for the reconstruction of the series, the important points are two: namely, (*a*) that the subjects received the links in chance order, and (*b*) that they were compelled to deal with the series link by link and were not allowed to do so *en masse*.

a. In presenting the colors and syllables, the experimenter shuffled the paper-squares and cards, drew the units one by one and laid them down on the table for the subject to take up and place. The scent bottles were mixed as they stood on the table and the blindfolded subject was then—ordinarily—herself allowed to take them up at random. Thus, in the case of the smells, all danger was avoided of caprice in selection on the part of the experimenter. The order in which the subject received or took up the units was one of the minor factors in determining the difficulty of any given attempt at reconstruction. The more nearly the units came to hand in their original order, the less likely the subject was to forget this order. A point of less importance is the fact that in all three sorts of series the first unit was presented (with the word 'first') to the subject, so that it might act as an initial suggestion or 'starter.' This practice was imitated from the original procedure of Ebbinghaus.[1]

b. The meaning of the statement that the subjects were compelled to deal with the series link by link is this: The syllable-cards and the color-squares were not handed over to them in a sheaf or pack so that they might spread the series out before them and look back and forth from one unit to another before any of the units were placed. Neither were they allowed to smell the same scent-bottles repeatedly during any one attempt at rearrangement. Reconstruction under such circumstances would be to a very considerable extent a matter of inference. The difference between pure memory and partial inference may

[1] *Ueber das Gedächnis*, p. 31, phrase, *nach gegebenem Aufgangsglied*.

be illustrated thus: A subject may argue that '*lek* must come after *pux* because *pux* was followed by some syllable with a short *e* and all the other syllables with a short *e* seem to belong somewhere else.' In this case he does not really remember the sequence *pux—lek* but only the sequence *pux—ĕ*. It is, of course, impossible wholly to eliminate such inferences from the subject's mental processes in reconstruction. Indeed, inferences of the same sort play no small part in reproduction by the most delicate of all the memory-methods—that of right associates.[1] In the reconstruction of series, as the process nears completion, inference becomes more valuable and memory becomes less essential until finally the subject puts the last unit left over into the last vacant place with a satisfied feeling that it 'must belong there.' The value of inference is, however, minimised when the subject receives the links one by one, and is compelled to indicate once for all his best judgment of the position of each with reference to those already placed.

At this point, we encounter an important difference between the three sorts of material. In the case of the colors and syllables, the subjects could see the units which they had already placed; in the case of the smells, they were forced to remember the placing which they had already done. Therefore, in the case of the colors and syllables, more could be done by inference. Furthermore, 'reproductive reinforcement' may have come into play in a much more marked fashion. Reproductive reinforcement is the opposite of reproductive inhibition; it is the working together of two or more associations in reviving some idea which no one of them, taken singly, might be strong enough to reproduce.[2] It may be illustrated thus: A subject may take up a particular brown and be unable to remember anything in regard to its place or neighbors until the sight of a dark green already placed suggests that this brown came after a light green. Thus the brown and the dark green together

[1] Cf. Müller and Pilzecker, *Experimentelle Beitrage zur Lehre vom Gedächtniss*, Zeitschrift f. Psych. und Phys. der Sinnesorgane, Ergänzungsband, i. pp. 16–17.

[2] Cf. Ebbinghaus, *Grundzüge der Psychologie*, Bd. i, 2te Auflage, pp. 698–700 on 'assoziative Förderung.' Cf. also Müller and Pilzecker, *op. cit.*, pp. 82–83.

suggest the light green. Of course, reproductive reinforcement can occur in the smell-series also, but there can be no simultaneous perception of different smells. One of the suggesting smell-links must always be a mere memory-image.

III. It is necessary to explain in even tedious detail exactly what is meant by the 'perfect' reconstruction of a series. In the method of complete memorising (the original method of Ebbinghaus, later elaborated by Müller and Schumann), a series is not considered as mastered until it can be repeated (*a*) without mistakes, (*b*) without hesitation, and (*c*) with consciousness of correctness. With our own method, we attempted to apply equivalent rules:

a. A displacement of two units even in the longest series made the reconstruction imperfect. This rule requires no further discussion.

b. Our placing rules were adopted as an equivalent to the rule in regard to hesitation. As may be remembered (see page 3), they were, briefly, that no reconstruction should count as perfect (1) in which the relative positions of any series-members had been corrected by transposition, (2) in which a space had been made between any two members already placed for the insertion of a third, or (3) in which members properly standing next to each other had not been made to touch from the first. These rules are not a perfect equivalent to the hesitation-rule of Ebbinghaus. The principle upon which the hesitation-rule is adopted in the method of complete memorising is doubtless, primarily, that firmly established associations work rapidly. In experiments by the reconstruction method it is impracticable to limit exactly the time given the subject for the placing of the several units. (He has them in his own hand.) The hesitation-rule has, however, a secondary value in insuring that the series is recited from memory without the aid of inference, for even when a series of words or syllables is recited from beginning to end there is opportunity for inference if the subject is allowed unlimited time. Arbitrary as the placing-rules seem, they were adopted after preliminary experiments as the only way of making sure that memory played the major and inference the minor

part in reconstruction. The operation of these rules must be illustrated in detail.

Let us suppose that we are dealing with a series of 26 scent-bottles and let us represent them in order by the letters of the alphabet. The positions which the subject gives to the bottles must indicate from the moment in which he sets them down upon the table positions in the series relative to all the bottles which he has so far placed. The subject knows more or less exactly the length of the series and arranges it from left to right with the middle of the series approximately opposite his own 'median line.' He first receives the bottle *a*, is told that it is the first, and places it to the extreme left of the space required for the series, He then receives *w*, knows that it is one of the last scents, and places it considerably to the right of this space. Next he receives *l;* this he places between *a* and *w*. Next he receives *j*. This he must place between *a* and *l* without letting it touch either. It is not necessary that he should at once put it nearer *l* than *a*. Such a demand would make his task much harder, and would, moreover, put a premium upon absolute space-associations. If, however, he puts the bottle between *l* and *w* or lets it touch *a* or *l*, then the reconstruction cannot be perfect unless he corrects his mistake before he has smelled another scent. (The smelling of another odor might, of course, reveal his mistake.) If he is a practiced subject and knows the series, he will place the *j*-bottle near *l* on the left, rapidly measuring out with his finger the space necessary for *k*. Next comes the bottle *y*; this must be made to touch *w* on the left; if a space is left till the next scent is smelled, the reconstruction cannot be perfect. Thus he proceeds, bottle by bottle. If he has allowed too much space for the series, he must push the short rows together as soon as he has the bottles which belong between them. For instance, *j-k-l* and *n-o-p* may be standing far apart, but as soon as *m* appears he must make a compact row from *j* to *p*. Let us now suppose that twenty-five bottles are placed, and that only one space remains, a space between *r* and *t*. He now takes up his last bottle, and discovers, to his distress, that it is *c* and that he has mistaken *s* for *c* and has already put it in between *b* and *d*. He may and must now put both *c* and *s*

in their proper places, but although this may be the only error of placing which he has made, the transposition makes the reconstruction 'imperfect.'

Our subjects were not required to arrange the series from left to right. Some of them arranged the links from right to left, and at least one subject arranged them in a line perpendicular to her own person. In the case of long series each individual subject was required always to put the same number of units of each kind—scent-bottles, color-squares, or syllable-cards—in one row. Otherwise, the experimenter could not have been sure whether the subject was beginning a new row, or was putting certain units aside for the moment because she could remember nothing about them.

The subjects were allowed temporarily to lay aside a unit during the process of reconstruction. Of course, no reconstruction in which this had been done even once was accounted perfect. Nevertheless the practice was a deviation from the strict link-by-link procedure. It was allowed on the ground that if the subject were compelled to insert a unit at random a source of confusion would be introduced to which many misplacements might be due. It was a mistake, however, to make an exception for such cases of total ignorance. Every error which the subject makes, wittingly or unwittingly, reduces the chance that the rest of the series will be correctly reconstructed. To be sure, if the subject is compelled to place a unit absolutely at random, he does so with great dissatisfaction, and is likely to arrange the rest of the series somewhat recklessly. Still, in a minor degree, every uncertain placing tends to produce this same unfavorable mood. It should be noted, however, that except as a last resort, no subject laid aside a unit unless she had already broken a placing-rule or thought that she had already made some other mistake. 'To do the series all over again' was the penalty of such delay, and unless this penalty had already been incurred, the subject preferred 'to take chances' in placing the unit at once. Scent-bottles set aside might not be re-smelled.

c. No reconstruction was counted perfect unless it was made with some consciousness of correctness, that is, unless the sub-

ject (1) had placed the links, one by one, in what she definitely 'supposed' (conjectured) to be the proper places, and (2) in the end knew of no mistakes which she had made. When a reconstruction was complete, the experimenter asked, 'Is it right?' If the subject said 'Yes,' the experimenter inquired, 'Are you sure or do you only bet on it?' If the subject answered that she 'only betted,' the reconstruction was reckoned as imperfect. If she said that she was 'sure,' the reconstruction was counted as perfect, provided that it was objectively correct. Nevertheless, the word 'sure' covers the most varying degrees of certainty.[1] The observers undoubtedly too often said they were sure when they would have hesitated to 'stake' ten cents on the correctness of the rearrangement. For if the subject merely 'bet,' the series had to be again presented and again reconstructed, and this penalty constituted for the subjects—even for G., the director of the experiments—an insupportable temptation to construe themselvs a trifle more certain than they really were. Except in the case of G., almost no cases appear in the records in which the subject had reconstructed the series without breaking the placing-rules and yet only 'bet' that it was right. Cases practically never occur in which the reconstruction was really correct but was nevertheless supposed by the subject to be wrong. We unfortunately omitted to count the many reverse cases in which the subject asserted or 'bet' that a wrong reconstruction was right. Our results, therefore, furnish very few reliable data in regard to the consciousness of certainty. It must, however, be remembered that *the placing-rules practically eliminated the possibility of a perfect reconstruction by guesswork.*

To keep the placing-rules and to be perfectly sure that a completed reconstruction is correct is harder with the colors than with the nonsense-syllables, and harder still with the smells than with the colors. In the case of the syllables, the

[1] On variations in the consciousness of correctness, Cf. Müller and Schumann, *op. cit.*, p. 305; Müller and Pilzecker, *op. cit.*, pp. 9 and 16–18; Ephrussi, *Experimentelle Beiträge zur Lehre vom Gedächtnis;* same Zeitschrift, xxxvii, pp. 90–95.

subject has only to memorise the order of perfectly distinguishable units and to avoid careless mistakes. In the case of the colors and smells, he must not only do this but may have difficulty in identifying some of the units as those belonging in particular places. Moreover, in the case of the smells, he may forget the contents of some of the bottles which he has already placed in the half-formed row. It will be remembered that no subject was allowed during any one attempt at reconstruction, to smell any scent again after she had once placed it and had smelled another bottle. Therefore, the subjects had not only to recall the order of the series, but also constantly to remember the contents of the bottles which they had already placed. The subject of the illustration, with *p* in his hand, might not be able to remember whether a given bottle in the row before him was *n* or *q*. If he set the bottles *f* and *v* aside, he would be able afterwards to tell which was which only by the spatial positions which he had arbitrarily given them. The rule under discussion was designed, not only, like the placing-rules, to minimise the tentative, shifting reconstruction of the series, but also to put a premium upon smell-images. It was perpetuated to the end of the smell-work in order that the later experiments might be comparable with the earlier. Breaking this particular rule was considered as a misdemeanor of the same order as turning over the color-squares to look at the symbols on the back. However, it obviously made the conditions of the smell-experiments very different from those of the color- and syllable-experiments, in which the subjects gradually spread the series out before their eyes. This point will be taken up again in Chapter V. It may be noted here in passing that this peculiar difficulty in arranging the smell series has little to do with the fact that the subjects were blindfolded. If the experiment is to be even in the loosest sense an experiment in memorising series of smells, the subject cannot be allowed to *see* any difference in the scent-bottles. Without the eye-bandage, he has still the double task of remembering the series-order and the contents of the bottles which he has already placed.[1]

[1] The conditions of the experiments with 'visible series,' on the one hand, and with smells, on the other, might have been made more comparable by either of

IV. In precise experiments in memorising the following time-intervals are of importance: (*a*) The exposure-time of the various units; (*b*) the vacant interval between these exposure-times; (*c*) the interval between the end of one presentation of the series as a whole and the beginning of the next presentation; (*d*) the interval between the last presentation or last of a series of presentations of the series as a whole and the beginning of the reproduction which corresponds to this presentation or series of presentations; (*e*) the time allowed to the subject or required by him for reproduction; (*f*) the interval given for rest between the learnings of different series at the same sitting; and (*g*) the interval between the different experimental sittings. In connection with this list of intervals, two other circumstances may properly be discussed, viz: (*h*) the hour of the day at which the experiments are made, and (*i*) the time-order (*Zeitlage*) of series of different kinds which may be given at the same sitting. In regard to nearly all of these matters, our own experimental conditions, in the reconstruction-work, were irregular, and our records rough.

a and *b*. The exposure-time of the several units in a series and the vacant interval between the exposures together determine the *rate of presentation*. In describing our experiments these two factors must be treated together.

The mere fact that we did not use apparatus in the reconstruction, experiments made the rate of presentation both slow and irregular. Nevertheless, it would be a mistake to suppose that by the practiced experimenters the series were presented with great irregularity. On the contrary, irregularity in the intervals was inappreciable *except as it was created by the subjects themselves* in 'holding on' to a bottle or by remonstrating over the removal of a color which they had not had 'time to see'.

two methods. Either the subject might have been allowed to re-smell bottles whose places had already been definitely assigned, or else the color-squares and syllable-cards might have been covered individually with blank cards as soon as placed. (For certain reasons, covering them would be more convenient than turning them upside down.) The first method we rejected for the reasons stated in the text. The second method did not occur to us when the main body of experiments was made. Its results have been, to some extent, tested by a small set of control-experiments included in Group V.

By the practiced experimenters, the colors and syllables were presented at intervals of $3\frac{1}{2}$ seconds (by some individuals at intervals of 4 seconds) almost as regularly as if the timing had been done with a watch or metronome. As a matter of fact, it was done by the movements of the experimenter's arm. The latter was not allowed both to expose and to remove a color-square or syllable-card with a single outward and inward arm-movement. On the contrary, she was required, when she had laid down a paper or card, to take her hand completely out of the space above the table and to bring it back to take up the paper or card. This movement was almost always made as rapidly as possible, and not only insured to the subject an unobstructed view of the syllable or color but timed its exposure. The exposure lasted between one and two seconds or rather less than one-half of the total interval between the beginnings of successive exposures. The automatic movements of the practiced experimenters were all regulated to *approximately* the same rate in each group of experiments since all these experimenters worked many hours with the principal subject G., who protested at once upon any deviation from the rate to which she was at the time accustomed.

In the smell-series the exposure-time was much more irregular than in the color- and syllable-series, because the subjects took the scent-bottles into their own hands, whereas they were not allowed to touch the color-squares and syllable-cards, and because very different lengths of time are really required to apprehend (*auffassen*) the various units. A rule was made that only 'one good sniff' with each nostril might be taken, but as a matter of fact, a subject was very rarely deprived of a bottle by the experimenter, who could not well take it upon herself to decide the time required for apprehension in the particular case. Indeed, in all three sorts of series we proceeded upon the assumption that uniformity in the satisfactoriness of the subject's apprehension of the units was more important than uniformity in the rate of presentation. Therefore the subjects were allowed at any time to delay the farther presentation of a series until they had satisfied themselves as to the nature of a unit. It must be confessed that in the first presentation of a smell-series,

a subject often retained a bottle until she could name the odor. However, this puzzling over the name, irregular as it made some of the intervals, tended to prevent the review of foregoing units.

In the presentation of the smell-series, the rate was not only more irregular but was also slower than in the case of the 'visible' series. It was retarded simply by the fact that smells are apprehended more slowly—at best—than colors are 'grasped' or syllables read.[1] (The manipulation of the bottle stoppers became after a little practice a very automatic and rapid affair.) Of course, the later presentations of the smell-series took place more rapidly and more regularly than the first presentation because the subjects relinquished the bottles more rapidly and at more regular intervals.

In the case of the subject G., eleven or twelve bottles to the minute was the ordinary rate in the first presentation. This rate would give an average interval of from 5 to 5.5 seconds from the beginning of one exposure to that of the next. The average interval is approximately also the most ordinary interval. Of this total interval, the exposure occupied fully half. In the case of the other subjects, the average interval and the ordinary or normal interval do not correspond at all on account of the large number of intervals greatly in excess of the normal. Certainly the rate of twelve bottles to the minute was rarely, if ever, exceeded with any subject in the first presentation of a series.

At this point, the question may arise as to why the intervals with the three kinds of series were not all made so long that they could be uniform. The reason is this: The intervals—all exceedingly long in comparison with the intervals in most other memory experiments—were, so to speak, already subjectively equal, i.e., they allowed the subjects the same small margin of vacant time. In the smell-experiments, the attention of the subjects was pretty fully taken up in receiving the bottles, and in uncorking, smelling, recorking, and setting them down. In the other experiments, attention was largely absorbed in looking at the colors or reading the syllables and in watching in expectancy the rapid hand-movements of the experimenter.

[1] On the slowness of smell-reaction time, cf. Zwaardemaker, *op. cit.*, p. 202.

If, however, the colors and syllables had been presented as slowly as the smells, the subjects would have had *at least* one full second of vacant time to each unit, an interval during which their mental occupation would have been difficult to control.

The crucial question of exactly what the subjects *did* do during the presentation of a series must be answered in connection with the introspective results. Nevertheless, two possible consequences of the slow rate of presentation should be explained in connection with this preliminary discussion of method. Let us again represent the units of a series by the letters of the alphabet in order. Now, in the first place, if the links are exposed for a long time and at long intervals, then during the exposure, say, of *e*, and during the interval between *e* and *f*, there may be time for a peculiar clinching of the association $\overset{\frown}{d\ e}$. By the aid either of a visual or of a verbal image, the subject may bring the two links into the same mental content, almost as if they were presented simultaneously. This he cannot do if the series is presented very rapidly, not because the link *d* does not *tend* to 'persist,' but because his whole time between *d* and *f* is occupied in 'grasping' *e*. In rapid presentation, he has a set of more or less discrete experiences, *a*, *b*, *c*, *d*, *e*, and so on. In slow presentation,—even if only the intervals and not the exposure times be long,—he may have a set of linked experiences, either *a*—*b*, *b*—*c*, *c*—*d*, *d*—*e*, etc., or *a*—*one*, *b*—*two*, *c*—*three*, or the like. In the second place, as a consequence of slow presentation, some 'quick-witted' subjects may have an opportunity in the interval, say, between *e* and *f*, to review the sequence *c*—*d* or even to go back as far as *a*—*b*—*c*. This possibility has been already suggested (p. 11). A third and more obvious consequence (already mentioned) is the temptation to use mnemonic devices.

c. The intervals between the several presentations of the series as a whole were unavoidably irregular, because every presentation of a series was followed by an attempt at reconstruction and because these attempts consumed a very variable amount of time. This amount depended (1) upon the length of the series and (2) upon the order in which the subject received or took up the units. The lengthening of the series made the

interval between the presentations longer because the subject had more units to place, because the experimenter had a longer record to make, and because the experimenter had more units to rearrange in the proper order for the next presentation. Thus, in the longer series, a longer interval supervened *between the presentations of the same sequence* both because the *rest of the series* took more time for presentation, and because longer intervals supervened between the several presentations. The longer series had, therefore, in a marked degree the advantage of 'distributed repetitions' (*Verteilung der Wiederholungen*).[1]

d. The interval between the presentation and reconstruction of a series was comparatively though not strictly regular. It consisted simply of the amount of time which the experimenter took to mix or shuffle the units to her own satisfaction. Thirty seconds is an ample estimate for the shuffling of a card- or syllable-series of 41 units. A rather longer time was required for mixing the scent-bottles than for shuffling the colors and cards. During this interval there was neither instruction nor distraction to prevent the subjects from reviewing some part of the series if they cared to do so.[2]

e. The period required for the reconstruction of a series was not in general timed. This omission was unfortunate. As regards the individual subject, the times have little significance since they vary with the chance order in which the subject was compelled to deal with the several links (cf. page 32). Nevertheless, gross variations as regards the time consumed in reconstruction seem to have constituted one of the most important individual differences between the subjects. There are abundant indications of this fact in the results although no exact figures can be given. In all cases, the reconstruction time greatly exceeded and usually it at least doubled the presentation time, since the subjects were allowed to reflect as long as

[1] See Ebbinghaus, *Grundzüge*, pp. 657–660 and *Jost, Die Assoziationsfestigkeit in ihrer Abhängigkeit von der Verteilung der Wiederholungen*, Zeitschrift f. Psych. und Phys. der Sinnesorgane Bd. xiv, pp. 436–472.

[2] This was one of the instances in which the director preferred to have no regulation rather than to risk that peculiar lack of uniformity which is enta ed by a rule imperfectly kept. It must not be forgotten that the experimenters and subjects were many.

they liked upon the placing of each unit. In general, the first reconstructions of a series required more time than the later, but occasionally at the first attempt a subject would place the units hastily and at random rather than waste time upon a reconstruction which would be in any case incorrect.

f. The intervals between the memorisings of different series at the same sitting were also irregular. When one series had been perfectly reproduced, another was given as soon as the experimenter could make and record it. If prepared before the beginning of the sitting, it was presented at once without more than a two-minute interval for rest. In these experiments, the whole process of presentation and reproduction was so leisurely, that the strain upon the subject was relatively insignificant except in special cases which will be noted later. As many series were given at one sitting as the time allowed. The sitting was ordinarily forty-five minutes long. This period *barely* allowed a series of forty-one smells to be three times presented to the subject G., and three times reconstructed, and these three rearrangements to be properly recorded. A series of twelve smells could be once presented to G. and once reconstructed by her in three or four minutes.

g and *h*. The intervals between the experimental sittings and the hour of the day at which the experiments were made varied much from one subject to another, but were kept uniform from week to week. Details upon these points can best be given in connection with the results.

i. The number of series of different kinds which could be given at one sitting was too small and too variable to make stress upon their order at that sitting profitable. In general, only the influence of practice *from day to day* was considered in arranging a program of series to be memorised. At each sitting, the experimenter proceeded with the program as far as the time allowed. The effect which practice and fatigue might have within the limits of a given sitting were disregarded. Three types of program were in use: first, the haphazard program (more truly a lack of program) in which the order of occurrence of the different kinds of series depends on chance or on the caprice of the experimenters; second, the cyclic program in

which series of the different kinds (say, kind *a* and kind *b*) are used in strict rotation (thus, *a*, *b*, *a*, *b*, *a*, *b* and so on); and third, the compensating program (e. g., *a*, *b*, *b*, *a*; *b*, *a*, *a*, *b*; *b*, *a*, *a*, *b*; *a*, *b*, *b*, *a*, and so on); in which the order of occurrence equalises the effect of practice for the different kinds of series.

The most important points in this section are the following: (1) the series were presented to the subjects without the use of apparatus. No apparatus could be used in the smell-experiments. The color- and syllable-experiments were made for purposes of comparison. Therefore, no apparatus was used in them. (2) Vision, apart from visual imagery, was allowed to play no rôle whatever in the smell-experiments. (3) For rearrangement, the links of the series were given to the subject in chance order. This order was one of the minor factors in determining the difficulty of reconstruction. (4) The subject was required, as far as possible, to deal with each link singly, and once for all to indicate more or less exactly its place in the series by putting it into certain definite spatial relations with the links already placed. If the position of each link was not properly indicated before a new link was presented, the reconstruction was counted as imperfect. Thus, no perfect reconstruction could be a shifting, tentative reconstruction. (5) The requirement that the subject should deal with the links singly was, in the case of the color- and syllable-series, limited by the fact that the series were gradually spread out before the subject's eyes in the process of reconstruction. Thus, both inference and reproductive reinforcement were more important in the reconstruction of these series than in the case of the smell-series. (6) In the case of the smells, on the other hand, the subject had the double task of remembering the order of the series and the contents of the bottles which she had already placed. Thus, owing to the elimination of vision, the smell-series both lack an advantage possessed by the other series and are put at a positive disadvantage as compared with them. (7) The links of the smell-and color-series were presented for memorising at rather irregular intervals because time was allowed the subject to apprehend or 'grasp' the unequally

distinct units. (8) With all three sorts of material the presentations were very slow as compared with those in other memory experiments. This slowness was due in part to the lack of apparatus. In the case of the smell-experiments, the rate was retarded by the slowness with which smells are apprehended. In other words, the slow rate was due directly and indirectly to the nature of the material. (9) The slow rate of presentation tends to make it possible for the subject to grasp successive units in pairs, to review parts of the series while the presentation is still in progress, and to interpolate many connecting links between the units. (10) The longer series have by our method in a marked degree the advantage of distributed repetitions.

B. Treatment of the Numerical Results.

Experiments made by this form of the reconstruction method furnish several sets of numerical results. (I.) The experimenter may count (*a*) either the number of errors made upon any given attempt at reconstruction, or else (*b*) either (1) the number of sequences correctly reproduced or (2) the number of members given their true absolute positions in the series. (II.) He may also count (*a*) the number of repetitions necessary to secure the correct, and (*b*) the number necessary to secure the perfect reconstruction of the series. (III.) Finally, in a group of series of any one kind, he may count (*a*) the number of series which are correctly reconstructed, and (*b*) the number of series which are perfectly reconstructed at the first trial or upon any given number of trials.

I. In the number of right cases which are obtained after any given number of repetitions, one has a measure of the *degree* to which the subject has been able to master the series by means of this number of repetitions. We preferred to keep our accounts in terms rather of right cases than of errors, that is, in terms of what the subject did learn rather than in terms of what she did not. We counted two sorts of right cases, namely, (*a*) 'right sequences' and (*b*) 'right positions.' If a series represented by the twenty letters from *a* to *t* be arranged in the order *a—b—d—c—e—f— l—h—i—j— k—g—m—q —r—n—o—s—*

p—*t*, then this reconstruction contains seven right sequences,—namely, *a*—*b*, *e*—*f*, *h*—*i*, *i*—*j*, *j*—*k*, *q*—*r*, and *n*—*o*,—and nine right positions, that is, nine cases in which units—namely, *b*, *e*, *f*, *h*, *i*, *j*, *k*, *m*, and *t*—were put into places corresponding to their absolute numerical positions in the series. The putting of *a* into the first place was not usually counted as a 'right position' because the first link was generally handed to the subject with the statement that it was the first. Thus, in each series, the same number of right positions and of right sequences was possible, and this number was just one less than the number of units in the series.

Both methods of counting have a certain justification, and neither is entirely adequate without the other. This is clear from the illustration. If only the right sequences were reckoned no account would be taken of the fact that the subject knew that *t* was the last unit in the series; if only the right positions were reckoned no account would be taken of the fact that *r* was known to follow *q* and *o*, *n*. A reconstruction may furnish half the number of right positions possible without exhibiting any right sequences whatsoever; on the other hand, it may furnish only two less than the possible number of right sequences without exhibiting any right positions whatsoever. Let us suppose that a series consists of only nine members. Then the reconstruction, *a*—*d*—*c*—*b*—*e*—*h*—*g*—*f*—*i* illustrates the first possibility, and the reconstruction, *a*—*i*—*b*—*c*—*d*—*e*—*f*—*g*—*h* the second. Moreover, aside from the fact that neither method of counting alone can fully represent the accuracy of the reconstruction, it was worth while to count both sequences and positions because the results of the two methods of counting often enable the experimenter to check the introspective statement of the subject as to whether she had taken more pains to impress upon herself the sequences, or the positions of the units in the series.

Nevertheless, cases of extreme discrepancy between the results of the two methods of counting are rare. As a rule, the number of right positions exceeds the number of right sequences, but exceeds it only by a margin which is explicable from the fact that nearly every transposition of two members works

greater havoc with the sequences than with the positions. If the two members transposed do not stand next to each other, then we have four wrong sequences to two wrong positions unless one member is the last of the series; if they do stand next to each other, then we still have three wrong sequences to two wrong positions unless the two transposed members are the last of the series. (Note the results of transposing *c* and *d*, and *g* and *l* in the first illustration of reconstruction.) Because the results of the two methods of counting tally so closely, only the numbers of right sequences will be given in the numerical tables, except when the positions have some special significance.[1] However, in every group of series represented both sorts of wrong cases have been counted and the figures could be given.

Between the presentations of the series, the experimenter did not take time to count the right cases, but simply recorded the order in which the series-members were arranged. The numbers of the scent-bottles, the color-symbols, and the syllables were written in proper order in vertical columns at the left of the page. After the several trials, the numbers were written in parallel columns in the order which the subject had given to the series-members represented by them.

In massing the results for different series, absolutely no averaging was done. This is true even when the results were obtained from different subjects. When the numbers of right cases are presented in the form of per cents, the denominator of the fraction reduced to a per cent is always the *total* and *not* the *average* number of right cases possible, and the numerator is always the total number of right cases actually obtained.

II. Little need be said in regard to counting the number of repetitions necessary to a correct and to a perfect reconstruction, although the figures thus obtained are perhaps the most important which we have to offer. Of these numbers the arith-

[1] Sequences are chosen rather than positions because in some cases the subject abandoned the attempt to reconstruct a series after rearranging a few fragments of it. In these fragments, the right sequences might well be counted but the absolute positions of the units were not definitely enough indicated for the placing to be taken into account.

metical mean and the mean variation have been found for each 'set' or 'constellation' of series. It has not been worth while to find the central value because the numbers themselves which enter into the averages are for the most part so small (not *few* but *small*).

The writer should here emphasize the fact that by the expression 'number of repetitions'[1] and by the expression 'number of trials,' when used in connection with the reconstruction method, the reader is to understand a number of presentations followed each by a corresponding attempt at reconstruction. The writer does not know of any other set of memory-experiments in which *each* of a *number of complete* presentations has been followed by an attempt at reconstruction or reproduction.

In massing the results for different subjects, averages were never averaged. All results, when massed, were treated as if obtained from the same subject.

III. The third method of treating the results numerically requires some explanation and justification. This is the counting of the number of series of a given kind which are (*a*) correctly and (*b*) perfectly reconstructed upon the first or upon any given attempt. It may be thought that figures thus obtained can show nothing which would not emerge from the other two sets of figures. This is not wholly true. For other attempts at reconstruction than the first, this sort of counting is indeed of little importance. Nevertheless, when applied to the first attempt, it gives a notion of the subject's memory-span which cannot be given by the first set of figures and may not be given by the second. This point can be made clear by illustration. Suppose that from 10 series of 12 members each, 90 right cases are obtained. This gives an average of 9 right cases for each series. How can one tell from this average whether any of the series in question were right at the first trial or not? Again, suppose that 10 series of a given length are reproduced correctly upon an average of 1.5 trials. This would be the average if 5 of the series were correctly reconstructed at the first and 5 at the

[1] The word repetition is, of course, used inconsistently, like the German *Wiederholung*, to include the *first* presentation of the series.

second trial. In this case, it would be safe to say that the length in question lay just at the edge of the subject's memory-span. But 1.5 would be the average *also* if 9 of the 10 series were correctly reproduced at the first trial, whereas some one series 'ran over' to the sixth.[1] In this second case it would be fair to say that this series-length lay within the subject's memory-span. Even the mean variation gives no adequate notion of the distribution of the numbers about the average. In the first of these two extreme cases, it is 0.5, whereas in the second it is only 0.9.

An elaboration of this third method of treatment consists in counting the numbers of series which are reconstructed at any given trial correctly, but with certain grades of imperfection. We considered the transposition of series-members a more serious fault than the making or leaving of a gap in the line, and any infringement of the spacing-rules a more serious fault than uncertainty in regard to the correctness of the reconstruction.

The figures obtained by this third method of counting were made to furnish per cents and not averages. The principle upon which results were massed was exactly the same as in the first method of counting. There was absolutely no averaging, either of the sums obtained in different sets of series or of per cents.

In brief, we have in the first method of counting as in the methods of right associates, prompting, and retained members, a method of determining the *degree of mastery obtained by any given number of presentations* short of the number necessary to complete mastery; we have in the second method of counting, as in the method of complete memorising, a means of determining *the number of presentations necessary to perfect mastery;* and lastly we have, in the third method of counting, a means of determining *the memory-span* for the serial order of different sorts of impressions.

[1] Such anomalous values occur frequently in all memory experiments and cannot fairly be thrown out. Cf. Müller and Schumann, *op. cit.*, pp. 272–274.

C. Preliminary Comparison with Other Methods of the Reconstruction Method as Used in These Experiments.

The purpose of this section is briefly to compare our form of the reconstruction method, first, with the reconstruction method of Münsterberg and Bigham, and second, with the various methods of memory-investigation in which series are memorised and their members (not merely the order of the members) reproduced.[1]

Ebbinghaus[2] divides methods of memory investigation into reproduction methods and recognition methods. Accepting this division as fundamental, the writer would farther divide the reproduction methods into (*a*) methods in which series are memorised and (*b*) methods in which the subject's more or less accidental associations with various words or objects are tested. These two classes of methods may be called for brevity (*a*) memorising methods[3] and (*b*) methods of free recall. The methods of free recall, namely, (1) the method of chance word-reaction or *Methode der zufälligen Wortreaction*, of Aschaffenburg and Wreschner and (2) the method of cursory enumeration, or *Methode des fortlaufenden Niederschreibens oder Aufzählens*, of Kræplin, do not concern us here. The methods in which series are memorised may be again divided (1) into methods in which the members of the series are reproduced and (2) the reconstruction method in which merely the order is reproduced.

I. The reconstruction method owes its name to Prof. G. E. Müller,[4] but, so far as the writer knows, it was first used by Münsterberg and Bigham in their study of 'the action of dis-

[1] The word *method*, as used without qualification in these pages, means a *memory-test method* and includes both an experimental and a numerical procedure. Any of the various *methods* of or for *memorising* which have been studied by Steffens, Ephrussi, and Ebert and Meumann—that is, the G-procedure or learning *im Ganzen*, the T-procedure or learning *in Teilen*, and so on—may form a part of any of the test-methods in which series are memorised.

[2] *Grundzüge*, p. 645.

[3] Not methods of memorising. See note, p. 41.

[4] This statement is made upon the authority of Pohlmann, *Experimentelle Beiträge zur Lehre vom Gedächtnis*, p. 5.

parate senses in recollection.'[1] As a matter of actual fact, our method was not devised in conscious imitation of Münsterberg and Bigham, but was gradually worked out as a method of testing the memory for smells without the use of words. Our aim was to make our method as much like the method of complete memorising as the materials and the object of the experiments would permit. Hence, the essential differences between our procedure and that of Münsterberg and Bigham. The first of these differences lies in the fact that we were not content simply to determine the extent to which the series order could be mastered by one presentation, but also strove to determine the number of presentations and attempts at reconstruction which were necessary to perfect mastery. In the Münsterberg and Bigham experiments each subject saw each series only once. The other essential difference consists in the pains which we took to avoid reconstruction by inference, guess-work, and tentative arrangement. Since Münsterberg and Bigham do not expressly say that they dealt out their color-squares and number-cards one by one during the process of reconstruction, we seem justified in assuming that they gave them over to the subjects *en masse*. In any case, they would certainly have mentioned the fact if they had had anything corresponding to our placing-rules, which, as already noted, were introduced to correspond with the rule about hesitation in the method of complete memorising. Non-essential differences, though matters of important detail, are the difference in the rate at which the series were presented, the fact that Münsterberg and Bigham used apparatus in presenting their color-and number-series, and the fact that they estimated degree of mastery only by counting errors of position ('the number of changes necessary to set the series right').

II. The reproduction methods in the narrower sense, that is, the methods in which *series* are memorised and their *members* and not merely the *order* of the members reproduced, are (1) the method of complete mastery or *Erlernungsmethode*, (2) the

[1] Studies from the Harvard Psychological Laboratory: *Memory*, Psychological Review, vol. i, pp. 34–38.

memory-span method or *Methode der Gedächtnisspanne*, (3) the method of right associates or *Treffermethode*, (4) the prompting method or *Methode von Hilfen*, and (5) the somewhat primitive method of retained members or *Methode der behaltenen Glieder*.[1] This subsection contains (*a*) a very brief sketch (inserted for the reader's convenience) of these five methods,[2] (*b*) an enumeration of the essential points of resemblance between our method and certain of the five, and (*c*) an explicit indication of the peculiarities of our method. It is unnecessary in this chapter to lay further stress upon the most obvious difference between our method and all the five, namely, the fact that they are reproduction methods in the narrower sense and are therefore suited only to verbal material, whereas our method is a reconstruction method and thus requires that merely the order of the series and not its members should be reproduced (cf. page 51 and Ch. I, page 10). Everything else which it is

[1] The reader is reminded (1) that the method of complete memorising was devised by Ebbinghaus for the pioneer experiments of *Ueber das Gedächtnis*, but was refined by Müller and Schumann (*op. cit.*); (2) that the *Methode der Gedächtnisspanne* was inaugurated by Jacobs (*Experiments in Prehension*, Mind, xiii, 1887), who was the first person to speak of a memory-span, and that it has in recent years been somewhat elaborated by Ebert and Meumann (*Ueber einige Grundfragen der Psychologie der Uhungsphänomene im Bereiche des Gedächtnisses*, Archiv fur die gesammte Psychologie, iv); (3) that the *Treffermethode* was elaborated by Müller and Pilzecker (*op. cit.*); (4) that the *Methode von Hilfen* was devised and named by Ebbinghaus and tested somewhat farther by Frl. Ephrussi (*op. cit.*); and (5) that the *Methode der behaltenen Glieder* received its name from Ebbinghaus but has been most carefully studied by Pohlmann (*op. cit.*). It is scarcely accurate to say that the *Treffermethode* was devised by Müller and Pilzecker, for in a simple form it had been used by Miss Calkins in her experiments in association. (*Association*, Psychological Review, Monograph Supplement, No. 2.) The *Treffermethode* of Müller and Pilzecker was first described by Jost (*op. cit.*). We need not here concern ourselves at all either with the reproduction-time measurements which are possible in the use of the *Treffermethode* nor with the applicability of the *Erlernungsmethode* to determining the number of repetitions which are 'economised' when series are relearned. The former received from Müller and Pilzecker the full name of *Treffer- und Zeitmethode*, and the latter from Ebbinghaus the name of *Erlernungs- und Esparnismethode*. The writer owes to Bergström the satisfactory translations of *Erlernungsmethode* and of *Treffermethode* used in the text. (*Effect of Changes in the Time Variables in Memorising*. Am. Jour. Psych. xviii.)

[2] A remarkably compact account of the different methods so far used in memory-investigation may be found in Pohlmann, pp. 2–7.

necessary to say upon this point will be reserved for the sixth chapter.

a. 1. In the method of complete memorising the subject goes over the series again and again (reading, hearing, or reciting) until he succeeds in reciting it without mistakes, without hesitation and with certainty of correctness. The presentations and reproductions all blend or may blend, except only the first presentation of the new series and the last perfect reproduction. At the beginning of any repetition of the series the subject may commence himself to recite it, but as soon as he hesitates or makes a mistake the experimenter presents the rest of the series to him. The experimenter counts the number of presentations necessary to the perfect recitation, usually including both the first presentation and the perfect recitation itself.

2. In the memory-span method, the experimenter finds how long a series can be reproduced in order without omissions or mistakes, or how long a series can be reproduced with only a given *quantum* of error, after a given number of presentations. The number of presentations is usually, but is not necessarily, one.[1] The experimenter begins with series which can be easily mastered with the given number of repetitions, and increases the series-length until the limit which he seeks to establish is reached. The procedure is akin to the method of limits in psychophysics. A descending procedure is sometimes added to the ascending procedure. In this method presentations and reproductions are distinct.

3. In the method of right associates, after the series has been presented to the subject a given number of times, alternate members are presented out of their original order, and upon each presentation the subject is required to name the member

[1] Bergström (*op. cit.*, p. 211). considers the method of retained members as a form of the memory-span method. Ebbinghaus, on the other hand, does not mention the memory-span method, although he does discuss the results of tests of immediate memory (*Grundzüge*, pp. 649–651). In the opinion of the writer, the term memory-span method *should only be* applied to a method in which the number of repetitions and degree of mastery are predetermined and in which series-length is the point to be determined (see text below), and it *may fairly be* applied to any such method, whether the number of repetitions be one or more.

just succeeding or sometimes the member just preceding. The experimenter counts the number of right associates, of partially right associates, of wrong associates, and of 'zero-cases.'

4. In the prompting method, after a given number of presentations, the subject is required to try to recite the series, and the experimenter counts the number of times when it is necessary to prompt or to correct him.

In these last two methods, the last presentation and the one reproduction blend. As Ebbinghaus points out, the one method is 'in a way the negative' of the other.

5. In the method of retained members, after a given number of presentations the subject is required to name as many members of the series as he remembers. The experimenter counts the total number named and notes the nature of the errors. Here again presentations and reproductions are distinct.

The various methods may be briefly compared as follows: In the method of complete memorising, the series-length is fixed; the degree of mastery to be attained is fixed, as perfect—i. e., as the degree necessary to recite the series without mistakes, without hesitation and with certainty of correctness,—and the *number of repetitions* necessary to attain this mastery is found by experiment. In the memory-span method, the degree of mastery to be attained is fixed—ordinarily, but not always, as perfect—the number of repetitions is fixed, and the *length of the series* which can be mastered to the required degree by the given number of repetitions is determined by experiment. In the other three methods, the series-length is fixed, the number of repetitions is fixed, and the *degree of mastery* which can be attained by this number of repetitions is found by experiment. The methods of complete memorising and of the memory-span are alike in requiring the complete memorising of the series; the other three methods are alike in not requiring it. In fact, in these last three methods it is essential that the number of repetitions should *not* be adequate to the mastery of a series of the length given, or at least that it should not be adequate in *both* of two groups of series which are to be compared. The first

two methods determine conditions of mastery; the last three, degree of mastery under different conditions.[1]

b. Our method is a kind of compound of the method of complete memorising, on the one hand, and of the method of retained members, on the other, and has in addition a certain kinship to the memory-span method. In the first place, our method, like the method of retained members, determines the fraction of the *total* content presented which can be memorised by a given number of repetitions, and tests this fraction without prompting. Presentation and reproduction are altogether separate affairs. The kinship between our method and the method of retained members is the most obvious of the resemblances under discussion. In the second place, our method, like the method of complete memorising, determines the number of repetitions necessary to complete mastery. In the third place, by finding the percentage of the total number of series of a given length which attain a given grade after a given number of presentations, our method gives some notion of the subject's memory-span. It should be explicitly noted that the writer is not restricting the expression memory-span to the span of the 'immediate memory,'—that is, to the amount which the subject can remember after a single rapid repetition of a series of impressions.[2] The product of immediate memory is a kind of centrally aroused after-image, and depends rather upon attention-span and upon 'persistence'[3] than upon facility in forming associative connections.[4]

Our method has least in common with the method of right associates. In this method, the subject is not required to reproduce the total content presented but only the half of it, and in the reproduction of this half the direct progressive (or else the direct regressive) associations are of almost exclusive importance, whereas in the reconstruction method, the associations between members of the series which do not stand next to each

[1] On the general distinction between methods which determine the conditions and methods which determine the degree of mastery, cf. Ebbinghaus, *Grundzüge*, p. 648, and Bergström, *op. cit.*, p. 210.

[2] Ebbinghaus, *Grundzüge*, pp. 649–650.

[3] See p. 204.

[4] *Cf.* Ebert and Meumann, *op. cit.*, pp. 204–206.

other, the 'criss-cross' associations, are of far more importance than in any of the other methods. Furthermore, the method of right associates furnishes more, and our own method less, opportunity for accurate measurements of the reproduction-time than any of the other methods under discussion.

c. Our method has two important peculiarities. One of these peculiarities has already been noted in the last paragraph but still requires some farther discussion. In the reconstruction method, the *direct regressive* associations (such as $\widehat{ba}$ or $\widehat{fe}$) and the 'cross' associations between units in the series which do not stand next to each other (such as $\widehat{eh}$ or $\widehat{gd}$) are far more important than in the reproduction methods proper. In these methods, the *direct progressive* associations (such as $\widehat{ab}$ and $\widehat{ef}$) are paramount. Two factors which are essential to the reconstruction method give relatively great importance to 'regressive' and 'cross' associations. The first of these is the premium put upon notions of absolute position in the series; the second is the projection of the whole series into spatial relations. In our experiments, the direct regressive associations were especially fostered by the placing-rules which made it quite as important for the subject to remember what a given link came after as what it came before. When a series is once learned by the reconstruction method, the units are bound together by *many threads of almost equal strength*, and these threads may leap over several intervening units and bind links which are relatively distant to each other.

The other respect in which our method stands alone is in requiring one reproduction (in the looser sense) of the series as a whole for every presentation of it as a whole. In the method of retained members, although reproduction and presentation are wholly separated, yet each series is tested but once, whether it is presented once or half a dozen times. The question arises as to whether or not in our method the *attempts at reconstruction* themselves contribute so much to the mastery of the series that one ought not to speak of the degree of mastery as conditioned, wholly or mainly, by the given number of *presentations*. The discussion of this question will be reserved for the critical exami-

nation of our method which will be made in Chapter VI on the basis of experimental results.

It may be noted here that if the question is answered in the affirmative, the explanation by multiplied tests is proved valid.[1] On the other hand, if it is answered in the negative, there would be no crucial objection in the methods of right associates, prompting, and retained members, to making a test of mastery after *each* of a series of presentations. Moreover, it might be admissible in the method of complete memorising to *prompt* the subject at each hesitation or mistake (instead of presenting the rest of the series *in toto*) and thus to gauge the *progress due to each repetition*.

[1] See p. 9.

CHAPTER IV.

NUMERICAL RESULTS OF EXPERIMENTS IN MEMORISING THE SERIAL ORDER OF SMELLS AND OF COLORS.

This chapter deals with the numerical results of the first three groups of experiments, which were all made by the reconstruction method and with smells and colors as material. The chapter falls into two sections.

A. Tables of Results with Explanation and Discussion.

I. Tables I—VI.

See tables on following pages.

II. Explanation of Tables.

a. The abbreviations with their meanings may be listed as follows:

L stands for *series-length* and *ML* for the *mean length of the series* in any one set.

N stands for the *number of series* (not the number of right cases possible) in any one set. *Nr* stands for the total number of series which *finally* were reconstructed *correctly* (rightly) and *Np* for the total number which *finally* were reconstructed *perfectly* in any one set.

RS stands for right sequences. *RS%* stands for the percentage which the right sequences, actually obtained upon any given trial in any set of series, form (taken together) of the right sequences which were numerically possible in that set upon that trial. (See illustration on page 68.)

RP and *RP%* will be used in a strictly analogous fashion for *right positions*.

W stands for *number of repetitions*. (The symbol *W*, initial of *Wiederholungen*, is selected for the sake of uniformity with the Ebbinghaus and Müller work.) *Wr* stands for *average number*

TABLE I.

Experiments of Group I., Subgroup 1 and Group II., Subgroup 1. Material: Smells. Subject: G.

PERIOD.	TOTAL NUMBER OF *R S* POSSIBLE.	*ML*	*N*	*Wr*	*Wp*	*RS* % *W* = 1	*ML*	*N*	*Wr*	*Wp*	*RS* % *W* = 1	*ML*	*N*	*Wr*	*Wp*	*RS* % *W* = 1	*ML*	*N*	*Wr*	*Wp*	*RS* % *W* = 1
I, 1	1919	9	**42**	1.7	.....	69	10	**97**	1.7	.....	72	11	**71**	2.0	.....	66	.....	.....	.....	.....	...
I, 2	2161	5.7	**172**	1.2	.....	88	7.3	**130**	1.2	.....	91	9.4	**39**	1.4	.....	82	11.3	**16**	1.6	.....	75
I, 3	739	8	**27**	1.1	.....	93	12	**22**	1.5	.....	84	16	**18**	1.8	.....	75	.....	.....	.....	.....	...
I, 4	3098	8	**17**	1.1	1.4	95	12	**84**	1.3	1.5	92	16	**97**	1.6	*N* = 96 2.0	81	20	**39**	1.8	2.0	78
II, 1	2270	12	**53**	1.4	1.8	91	15.6	**98**	1.5	*N* = 96 1.8	91	19.2	**51**	1.8	2.3	82	23.2	**6**	2.0	2.0	84
II, 2	990	16	**11**	1.2	1.4	98	19.8	**16**	1.6	2.0	78	23.2	**5**	2.6	2.8	56	27.8	**4**	2.0	2.8	61
II, 3	1351	15.3	**12**	1.3	1.6	92	19	**21**	1.6	1.8	80	22.8	**21**	1.8	2.1	77	26.1	**11**	2.4	2.5	44
II, 4	2930	19.3	**12**	1.2	1.9	93	23.6	**26**	1.8	1.9	82	26.6	**32**	1.8	2.4	76	30.8	**25**	2.2	2.4	66
II, 5	1434	24	**4**	1.5	1.8	84	26.6	**7**	1.7	2.0	83	30.4	**12**	1.8	2.2	80	34.2	**5**	1.8	2.2	73
III., 1	1261	12	**27**	1.3 *N* = 13	*N* = 26 1.5 *N* = 8	94	16.2	**9**	1.3 *N* = 6	1.4 *N* = 2	88	21	**9**	*N* = 8 1.5	*N* = 7 1.9	86	41	**10**	*N* = 7 2.1	*N* = 6 2.5	55
III., 2	1680	41	**14**	2.2	2.1	68	81	**14**	2.2	2.0	48	.....	.....	.....	.....	...	.....	.....	.....	.....	...

TABLE II

Experiments of Group I., Subgroup 2. Material: Smells

Subject.	Period.	Total Number of *RS* possible.	L: 5, 6, 7, 8							L: 9, 10, 11, 12							L: 13, 14, 15, 16						
			ML	*N*	*Nr*	*Wr*	*Np*	*Wp*	*RS* % *W* = 1	*ML*	*N*	*Nr*	*Wr*	*Np*	*Wp*	*RS* % *W* = 1	*ML*	*N*	*Nr*	*Wr*	*Np*	*Wp*	*RS* % *W* = 1
E.	1	338	6.7	**40**	39	2.7	39	3.2	.....	10	**7**	7	4.0	7	4.6	.....	.....	.....	...	.....	...	.....	.....
	2	304	7.6	**14**	14	2.9	14	3.1	48	10.1	**14**	14	4.0	14	4.6	40	14.4	**5**	0	....	0	....	12
	3	553	7.2	**13**	13	1.8	13	2.1	75	10.6	**32**	30	2.3	29	2.5	50	14.8	**12**	11	3.0	11	3.2	37
F.	1	458	6.8	**48**	48	2.1	48	2.5	.....	10.1	**13**	13	3.0	13	3.8	.....	.....	.....	...	.....	...	.....	.....
	2	425	7.1	**17**	17	1.6	17	2.1	77	10.2	**25**	24	2.4	24	2.8	44	14.3	**7**	6	3.3	5	3.4	30
	3	314	7.7	**6**	6	1.2	6	1.3	93	10.8	**15**	13	2.2	13	2.3	42	15.	**9**	8	2.6	8	2.9	32
Ha.	1	279	6.4	**36**	36	1.3	35	1.6	.....	9.8	**5**	5	2.0	5	2.8	.....	.....	.....	...	.....	...	.....	.....
	2	588	7.2	**33**	33	1.2	33	1.3	89	10.3	**41**	41	1.6	41	1.7	81	14.5	**12**	12	1.9	12	2.3	65
He.	1	559	7·	**50**	50	1.3	50	1.4	.....	10.	**22**	22	1.9	22	2.1	.....	.....	.....	...	.....	...	.....	.....
	2	496	7.1	**11**	11	1.2	11	1.3	96	10.5	**24**	24	1.2	24	1.4	93	.....	.....	...	.....	...	.....	.....
Hu.	1	296	6.6	**45**	44	1.8	43	2.3	.....	.....	.....	...	.....	...	.....	.....	.....	.....	...	.....	...	.....	.....
	2	438	7.1	**21**	21	1.8	21	2.0	73	10.1	**28**	25	2.8	25	3.4	58	.....	.....	...	.....	...	.....	.....
	3	651	7.4	**10**	10	1.4	9	1.8	80	10.8	**21**	20	1.2	20	1.6	84	14.9	**12**	10	2.8	10	3.2	40
Wa.	1	202	6.8	**27**	27	1.2	27	1.5	.....	.....	.....	...	.....	...	.....	.....	.....	.....	...	.....	...	.....	.....
	2	567	7.2	**29**	29	1.0	29	1.1	100	10.2	**32**	32	1.2	32	1.4	93	.....	.....	...	.....	...	.....	.....
	3	557	.....	.....	...	.....	...	.....	.....	10.8	**17**	16	1.3	16	1.7	85	15.1	**10**	8	1.0	8	1.3	94

TABLE III

Experiments of Group II, Subgroup 2. Material: Smells

Subject.	Period.	Total Number of *R S* possible.	*L*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1	*L*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1
D.	II, 1	1741	31	**35**	33	2.0	0.4	24	2.2	0.3	80	61	**11**	10	2.8	0.5	6	3.2	0.6	43
	II, 2	760	41	**9**	9	2.0	0	5	2.0	0	65	81	**5**	2	3.0	0	1	3.0	.....	27
Gr.	1	297	12	**27**	24	2.6	1.0	20	2.5	0.8	49	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	297	12	**27**	26	1.9	0.5	26	2.1	0.6	62	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	225	26	**3**	3	3.0	0	2	3.0	0	41	51	**3**	0	.....	.....	0	.....	.....	17
R.	1	429	12	**39**	39	2.3	0.8	39	2.4	0.9	59	.....	.....	.....	.....	.....	.....	.....	.....	.....
	2	610	12	**39**	39	1.5	0.5	39	1.6	0.5	79	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	350	26	**8**	6	2.3	0.4	6	2.3	0.4	33	51	**3**	1	3.0	.....	0	.....	.....	18

TABLE IV

Experiments of Group II, Subgroup 3 and Group III., Subgroup 3

Material.	Subjects.	Period.	Number of *R S* possible	*L*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1	*L*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1
Smells	8 beginners	1	2515	12	**88**	69	2.7	1.1	55	2.9	1.1	43	18	**91**	44	3.3	1.0	25	3.4	1.1	27
		2	1147	12	**44**	42	1.7	0.6	33	1.7	0.6	69	18	**39**	30	2.5	0.7	14	2.7	0.7	49
		1–2	3662	12	**132**	111	2.3	1.0	88	2.4	1.1	51	18	**130**	74	2.9	0.8	39	3.1	0.9	34
Colors	15 beginnners	1	3304	12	**118**	117	2.2	0.6	108	2.6	0.8	50	18	**118**	116	3.4	0.9	108	3.9	1.1	32
		2	2940	12	**105**	104	1.8	0.5	100	2.1	0.5	70	18	**105**	104	2.7	0.9	100	3.0	0.8	44
		3	2016	12	**72**	72	1.6	0.5	71	1.8	0.5	75	18	**72**	72	2.3	0.6	71	2.6	0.7	51
		1-2-3	8260	12	**295**	293	1.9	0.5	279	2.2	0.6	63	18	**295**	292	2.9	0.8	279	3.2	1.0	41

TABLE V.

Experiments of Group III, Subgroup 1. Material: Colors. Subject G.

PERIOD.	TOTAL NUMBER OF *R S* POSSIBLE.	*ML*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1
I, 1	310	7.3	**6**	6	1.2	0.6	6	1.3	0.6	92
		10.6	**19**	19	1.4	0.5	19	1.9	0.5	83
		13.7	**15**	15	1.9	0.5	15	2.1	0.3	56
I, 2	473	11.6	**8**	8	1.4	0.5	8	1.6	0.6	84
		14.5	**20**	20	1.5	0.7	20	2.2	0.8	86
		17.9	**7**	7	2.1	0.2	7	2.1	0.2	56
II, 1	2439	15	**8**	8	1.8	0.4	8	2.4	0.7	69
		18.5	**22**	22	2.5	0.8	22	3.3	1.1	65

PERIOD.	NUMBER OF *RS* POSSIBLE	*ML*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1
II, 1		22.6	**19**	19	2.0	0.3	19	2.3	0.5	56
		26.9	**48**	44	2.5	0.6	41	3.2	0.8	38
		29.9	**10**	8	2.6	0.5	6	3.2	0.6	38
II, 2	2360	41	**37**	28	3.1	0.5	22	3.8	0.5	24
		81	**11**	2	4.5	0.5	0	....	...	11
II, 3	1480	41	**11**	11	2.5	0.5	11	3.4	0.7	31
		81	**13**	12	4.4	0.6	3	6.0	1.3	11

TABLE VI.

Experiments of Group III., Subgroup 2. Material: Colors

Subject.	Period.	Total Number of *R S* possible.	*ML*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1	*ML*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1
He.	1	336	6.9	**12**	12	1.5	0.6	12	1.8	0.6	80	10.3	**20**	20	1.7	0.6	20	2.0	0.5	73
	2	661	11.2	**16**	16	1.3	0.4	16	1.4	0.5	87	14.2	**32**	32	1.9	0.6	32	2.2	0.7	67
Hu.	1	335	6.9	**13**	13	1.3	0.2	13	1.2	0.3	90	10.4	**23**	23	1.6	0.5	23	2.2	0.6	60
	2	408	11.6	**10**	10	1.5	0.5	10	1.9	0.5	81	14.1	**23**	23	2.1	0.9	23	2.4	0.6	54
Sm.	1	349	6.8	**11**	11	1.4	0.5	11	1.4	0.5	83	10.5	**19**	19	2.0	0.3	19	2.2	0.5	54
	2	531	11	**20**	20	1.9	0.7	20	2.2	0.6	64	14.3	**25**	25	2.3	0.4	25	2.6	0.6	38
C.	1	154	12	**14**	14	2.4	0.5	14	2.9	0.7	43	....	.....	.....	.....	.....	.....	.....	.....	.....
	2	757	12	**26**	26	2.0	0.3	26	2.2	0.4	55	18	**27**	27	2.6	0.7	27	3.1	0.5	37
	3	1681	20.6	**21**	20	2.4	0.5	19	2.7	0.7	32	30.5	**20**	18	3.1	0.7	17	3.3	0.8	24
			41	**17**	11	2.6	0.5	11	3.2	0.5	20	....	.....	.....	.....	.....	.....	.....	.....	.....
	4	460	21	**5**	5	2.2	0.7	5	2.4	0.6	56	31	**4**	4	2.3	0.4	4	2.5	0.5	37
			41	**6**	6	2.7	0.9	6	3.3	0.5	29	....	.....	.....	.....	.....	.....	.....	.....	.....
N.	1	138	12	**10**	10	3.3	0.8	10	3.9	0.7	22	....	.....	.....	.....	.....	.....	.....	.....	.....
	2	420	12	**15**	15	2.3	0.4	15	2.5	0.6	39	18	**15**	15	2.8	0.6	15	3.4	1.1	30
	3	1573	20.5	**16**	16	2.7	0.7	16	3.0	0.6	30	30.5	**17**	15	3.1	0.7	14	3.4	0.5	23
				19	14	2.9	0.3	12	3.3	0.4	15	....	.....	.....	.....	.....	.....	.....	.....	.....
			41																	

of repetitions necessary to a correct reconstruction. *Wp* stands for *average number of repetitions necessary to a perfect reconstruction.* *RS%*, *W* = 1 stands for *percentage of right sequences at the first trial.*

MV, of course, stands for mean variation.

The abbreviations listed will have the same meaning in all the tables of this monograph.

b. In explaining the general arrangement of the tables, the following points must be noted:

1. The work of each subject has been broken up into 'periods' according to the time-order of the experiments. This division was made to bring out the effect of practice. The periods are not, in general, equal divisions of time. Details as to the division will be given below. In the case of the subjects G. and D. the Roman numerals in the period-column give the academic-year periods of the reconstruction-experiments with a particular material, and the Arabic numerals give the subdivisions of these periods. Thus in Table I, the expression I, 4 means the fourth period of the first year and II, 1 the first period of the second year. Between these periods lay the long vacation; therefore we should expect a fall in the practice-level between I, 4 and II, 1. In general, the higher the numeral for the period, the higher the practice-level should be. On the other hand, sets of experiments given in the same period are all *approximately* upon the same practice-level.

2. The figures given in the column headed 'Number of Right Sequences Possible' are found by adding the right sequences possible for all the series of the period *upon the first trial.* In some cases, series are taken into this count which are not included in the sets of experiments covered by the columns to the right. In some periods, especially with the subject G., 'scattering' experiments were made with series of many lengths. It is not possible to find space in the tables for all these experiments, yet it seems important to indicate in some compact fashion the relative amount of practice obtained in the several periods. In general, the discarded series-lengths lay some just below and some just above the lengths included in the tables.

3. By 'set' of experiments is meant what the German writers mean by 'Konstellation,' that is, a number of experiments whose results of any one kind (value of *Wr*, *RS%*, or what not), taken together, make a unit or datum in the argument. In these first groups of experiments which have to do merely with the effects of practice and of series-length, a 'set' includes all the experiments upon a given subject with series of a given length or small group of lengths at the same practice-level.

To determine the effect of *practice*, one must examine the results obtained for series of the same length at different periods, working *downward* through the tables. On the other hand, to determine the effect of *series-length*, one must study the results obtained from series of different lengths in the same period, working *crosswise* through the tables.

4. The arithmetical work of massing series of different lengths in one set was done as follows: The mean length of all the series in the set was found, the numbers of possible and of actual right sequences in all the series were added together, and the values of *Wr* and *Wp* were found as if all the series in the set had been of the same length. It was, of course, by the 'scattering' of the series-lengths that such massing was made necessary. When no other arrangement is specified, the series are massed in groups of four,—the lengths 5, 6, and 7 with 8, 9, 10, and 11 with 12, and so on. A simple number (with no fraction) under *ML* of course indicates that the series in a set were all or nearly all of exactly the same length.

5. The reason why the percentage of right sequences is given only for the first trial is this: When the value of *Wr* is as small as it is in most of these experiments, the percentages of right sequences even on the second trial approximate too closely to be interesting. The relative amounts accomplished by successive repetitions will be discussed in the next chapter.

6. The reason why the figures under *N*, *Nr*, and *Np* are not always the same is that the end of the experimental sitting often came before a series, once presented, had been perfectly or even correctly reconstructed. When the number under *Np* is very small as compared with the corresponding number under *N*, nothing can be argued except that the time allowed for the

experiments was not long enough for dealing with so long a series. No series might be partially memorised at one sitting and finished at the next. This rule was rigidly enforced and in cases where it was broken, the results of the second sitting was thrown out on account of the distribution of the repetitions (*Verteilung der Weiderholungen*). In Table I, there is no room to make separate columns for Nr and Np. When these numbers differ from the number of series in the set they are inserted over the corresponding values of Wr and Wp after the expression N =.

To illustrate some of the statements in the last few paragraphs, let us take the results of the subject N from Table VI. Period 1 was given to preliminary practice. Ten series of the length 12 were given, making a total of 110 possible *RS*, 11 to a series. There were 24 actual *RS* on the first trial, putting all the series together. 24/110 = 21.8 per cent = $RS\%$. Besides these series, two of the length 15 were given tentatively. These contained 28 possible *RS*. 110 + 28 = 138, the number in the third column. In Period 2, the lengths 12 and 18 were compared. Thus this period contains two 'sets' of series. There were 15 series of each length. $(15 \times 11) + (15 \times 17) = 420$. In Period 3, the lengths of about 21, of about 31, and of 41 were compared. There were 8 series of the length 20 and 8 of the length 21, giving a mean length of 20.5. There were 9 of length 30 and 8 of length 31, giving a mean length of 30.5. $(8 \times 19) + (8 \times 20) + (9 \times 29) + (8 \times 30) + (19 \times 40) = 1573$. Of the 19 series of the length 41, only 14 ever attained to correct and only 12 to perfect reconstruction. If, however, one compares the values of Wr and Wp in this set of experiments with the values obtained by this subject in other sets, it is clear that the dropping out of so many series was due to the ending of the sitting (that is, to the limitations of the undergraduate schedule).

c. Certain rather tedious particulars must now be given in regard (1) to the general scheme of the experiments, (2) to the academic status of the subjects other than G., (3) to the division

of periods, (4) to the hours of the experimental sittings,[1] (5) to the time-order (*Zeitlage*) of the series, and (6) to the massing of the work on the beginners. The following scheme gives details upon some of these points:

GROUP I. Material: Smells.
Plan: To study smell-images and to reach the practice-limit in memorising order.
Subgroup 1. Subject: G.
Date and sittings: Periods I. 1–4: January–June, 1902; 12 per week.
Periods II. 1–5: September, 1902–May, 1903; 12–14 per week.
Subgroup 2. Subjects: E., F., Ha., He., Hu., and Wa.
Date and sittings: October, 1902–April, 1903; 2 or 3 per week (for each subject).

GROUP II. Material: Smells.
Plan: To study the effect of series-length.
Subgroup 1. Subject: G.
Date and sittings: Period III.[2] 1–2: September, 1903–May, 1904; 4 per week.
Subgroup 2. Subjects: D., Gr., and R.
Date and sittings: September, 1903–May, 1904; 2 or 3 per week.
Subgroup 3. Subjects: 8 beginners.
Date and sittings: 4 weeks, spring of 1904; 4 per week.

GROUP III. Material: Colors.
Plan: To study the effect of practice and of series-length.
Subgroup 1. Subject: G.
Date and sittings: Periods I. 1–2: January–June, 1903; 1 per week.
Periods II. 1–3: September, 1903–May, 1904; 6 per week.
Subgroup 2. Subjects: (1) He., Hu., and S; (2) C. and N.
Date and sittings: (1) January–June, 1903; 1 per week.
(2) September, 1903–May, 1904; 3 per week.
Subgroup 3. Subjects: 15 beginners.
Date and sittings: 4 weeks, spring of 1904; 4 per week.

[1] All statements as to hours and weeks refer to scheduled appointments. It should be understood both that subjects and experimenters sometimes 'cut' these appointments, and that the longer programs were broken by the short vacations and the mid-year examination period.

[2] *Period III* means the third year-period of G.'s work with smells. See p. 66.

1, *a*. The experiments of Group I broke the ground for all the succeeding experiments. They were of a tentative and unsystematic character. The experimenters intended 'to reach the practice-limit and then to try the effect of series-length.' It was supposed that practice would soon cease to increase except in a negligible degree. Ebbinghaus says in *Ueber das Gedächtnis*: ''The experiments fall into two periods; they were made in the years 1879–1880 and 1883–1884 and in each case *lasted fully a year*. The definite experiments of the first period were preceded during an ample length of time by tentative experiments of a similar kind, so that as regards all the results which are communicated, the time of increasing practice may be considered as *essentially passed over* (*wesentlich überwunden*). At the beginning of the second period care was taken to renew practice.''[1] Moreover, we had the authority of James for supposing that the effect of practice in memorising is exceedingly limited,[2] and it should be noted that our first experiments were made years before those of Ebert and Meumann, to say nothing of the still more recent experiments of Fracker. As a matter of fact, however, practice never did cease to increase. The experiments of this group always seemed preliminary, and the experimenters went on and on in a somewhat desultory fashion, giving the subjects longer and longer series and at the same time harking back to shorter series to see how well they could be done at the given practice-level. Hence, the 'scattering' of the series-lengths which is especially characteristic of this group of

[1] P. 45. The italics are the present writer's. Müller and Schumann, who made no such extended experiments upon any one subject as Ebbinghaus made upon himself, noted a continuous effect of practice in almost every series of experiments, and found no warrant for the assumption that a subject could be brought to a maximal degree of practice by steady work for a whole semester. Nevertheless, they did not find the effect of practice so great as to prevent them from reckoning the first and second halves of a series of experiments as homogeneous. The different series of experiments were, of course, preceded by enough preliminary experiments to raise practice beyond the levels of its first rapid increase. *Op. cit.*, pp. 327–328. See also pp. 88, 107, and 265.

[2] *Principles of Psychology*, pp. 663–668. Professor James holds only that one's native retentiveness cannot be improved. Nevertheless, his tone is such as distinctly to discourage memorising drill (stigmatised in one place as 'torture' and in another as 'heroic'), and he has been quoted as an almost classic authority against it.

experiments. The scattering was increased by the desire of the experimenters, in the interests of smell-imagery, to minimise number-associations. The experimenters did not announce the length of the new series, but 'jumped' from one length to another in a random fashion.

So great was the scattering of series-lengths in this group that it is not possible, even by massing in fours, to represent in the tables all the lengths employed. Nor is it possible in the tables which cover this group, Tables I and II, to find space for the mean variations from the average numbers of repetitions. These variations, however, run exactly as they do in the other experiments. Tables III to VI give an adequate notion of their size and irregularity.

b. The experiments of Group II were designed to make good the defect of Group I by comparing the effect of different series-lengths at the same practice-level. To the subjects whose results are massed, the lengths 12 and 18 were given without preliminary practice and according to a compensating program. The subjects who worked throughout the year were given one or two periods of preliminary practice. This training was given in the case of the new subjects, to accustom them to the smell material and to secure some method in their procedure. In G.'s case, it was given to raise the practice-level to that of the preceding year. After this preliminary work, series of two different lengths were given alternately. The length was known to the subject at starting. These series were long and therefore few. If the effect of series-length were to come out clearly, neither of the lengths compared might be so short that the subject could often learn the series with a single presentation. In each case, the subject required an hour and a half to learn the series of greater length. This time was obtained by putting two sittings together. The series were given alternately because it was impossible to work a 'compensating program' into the subjects' schedules.

c. The experiments of Group III, like those of Group I, cover nearly two academic years. The first year of Group III coincides with the second year of Group I, and partakes of the same general character. With the colors as with the smells the

experimenters made the same futile attempt to reach the practice-limit, indulged in the same scattering of series-lengths and made the same attempt to minimise number-associations. The second year of Group III corresponds with the one year of Group II and has the same general character. The experiments of the third sub-group in each period are exactly parallel.

The smell-series of Group II, were, apart from length, easier than the series of Group I, because better precautions were taken to avoid approximate duplicates (see page 26). On the other hand, the color-series of the second year were, apart from length, harder than those of the first. (See page 25.)

2. The subjects in the second sub-groups of experiments were all, except S. and D., members of a second-year class in psychology. S. was a graduate student and the pioneer experimenter in the smell-work. D. was a student in a third-year course, and had already served the year before in the reconstruction-experiments of Group VI. Gr. and R., C. and N. experimented upon each other as well as upon G. The meaning of the term 'beginners' has been explained in the preface.

3. The division of periods can best be discussed table by table. Table I covers all the work done upon the subject G. in these groups of experiments. In Periods I., 1–4, the principal experimenter, Miss Mary C. Smith, and the subject G. were occupied in working out the details of the reconstruction method used in all the later experiments with concrete material. In the first two periods, the subject was allowed to correct her work *ad libitum*, and to smell over again scents which she had already placed. If the first part of a series was reconstructed correctly, then on the next repetition the series was presented only from the point at which the subject's memory failed.[1] In the third period re-smelling was prohibited and the series were repeated always from the beginning. The placing-rules and system of grades were now invented and went into effect in Period 4. The method was then virtually complete. Periods II, 1–3 all fell

[1] This practice was in imitation of the method of complete memorising; it was dropped as needlessly confusing to the subject who had to have the series already pretty clearly in mind to recognize the 'passage' at which the experimenter would begin to repeat.

into the fall term of the second year. During this term the subject was suddenly given some series which were very long in comparison with the series to which she was then accustomed. These series are not taken into the tables (excepting into the second column). They had, however, considerable effect upon the subject's method of procedure. Period 1 covers the time before these series were given; Period 2, the time during which they were given, and Period 3 the time from the end of Period 2 to the Christmas vacation. Between Periods 3 and 4, there was a break of almost two months in the training. Period 4 ran from the early part of February till a change took place in the subject's method which enabled her to cope with long series as she had never been able to deal with them before. Period 5 covers this time of rapid progress. It is dated as beginning April 7 and ending May 7. Period III, 1 was devoted to making good any loss of practice during the second summer vacation, and falls into four sub-periods. The lengths massed in the table were *not* used turn about but in succession. First series of 12 were used; then of 16 and 18; then of 20, 21 and 24; then of 36 and 38 (not included in the tables); and finally of 41. The subject knew at starting the approximate but not always the exact length of the series. Period III, 2 covers the time when the lengths 41 and 81 were given alternately.[1]

In two periods in Table I., the grouping of series-lengths is not by fours. One is Period III, 1 where the grouping is according to the practice-levels. The other is Period I, 2 where the grouping is in pairs, 5 with 6, 7 with 8, and so on. Even in this period the subject began to learn the series in groups of four; has done so ever since, and has transferred the same method to the color-and syllable-series.

Table V covers the color-experiments upon G of Group III, Periods I, 1 and 2 are divided from each other arbitrarily to bring out the effect of practice. The first forty series given are included in Period I. Period II, 1 of the color-work is analogous to Period III, 1 of the smell work. The

[1] Such numbers as 31, 41, and 81 were taken for series-lengths in order that we might have such numbers as 30, 40, and 80 for the possible right sequences and positions.

different mean-lengths of the table represent slightly ascending practice-levels. The division between Periods III and IV corresponds to a slight time-break in the experiments.

In Table II, in Table IV, and in that part of Table VI, which covers the work of the subjects He., Hu., and Sm., the division of periods, though not quite arbitrary, is made upon slight grounds which it would be tedious to detail. In Table II the percentage of right sequences is not put down for the first practice period, because in this period the subjects very frequently refused to try to reconstruct the series, after a single presentation, and were not required to try.

In Table III, and in the latter part of Table VI, the division of periods was made according to the series-lengths used.

In the first year of the smell-experiments the subject G. worked at 9:00 a.m. and at 4:30 p.m. on the six weekdays. In the second year, she worked at 9:00 a.m. and 9:00 p.m. on the six weekdays and sometimes, but not always, on Sunday. The Sunday work was interpolated *not* to secure more result but expressly to test the effect of the day's rest. The appointments were kept with notable, though not unbroken, regularity. The sittings lasted from half an hour to an hour. In the third year of the smell-experiments most of the work was done between 2:30 and 4:30 p.m. It was not possible in the color-work of G. nor in any of the work done by other subjects, to keep the hours of the day even approximately the same from day to day, but the hours were kept uniform from week to week.

5. It has already been stated (page 44) that the effect of practice (and of *ennui*) could be considered only from day to day in making up the program of series-lengths to be used. In all cases where series of 20 or over 20 members were used, the program was a simple cyclic or alternating one, if there was a definite program at all. A compensating program for long series cannot be worked into an undergraduate schedule—at least, at Wellesley. In the work of the beginners with series of 12 and 18, a compensating program was carried out. In the smell-experiments of Group I and in the first year of the color-experiments, series of different lengths were given with great irregularity of order. In the work of G., the different lengths

were distributed evenly enough in the several practice-periods. But in the work covered by Table II, and in the work of He., Hu., and Sm. presented in Table VI, the series-lengths were distributed somewhat unevenly in the practice-periods. The experimenter gave rather more shorter series at the beginning and rather more longer series towards the end of the period. Therefore, the different sets of experiments which are supposed to be upon the same practice-level are not absolutely so; the longer series have *very slightly* the advantage.

6. The work of the beginners is massed exactly as if all the series had been obtained from the same subject. The irregularities in the value of N are due to the throwing out of many series.

III. Discussion of Results.

From the tables just discussed, one may draw the following conclusions:

a. The number of repetitions necessary to a perfect reconstruction (Wp) is extremely small as compared with the number necessary in the method of complete memorising for the perfect recitation of a series of nonsense-syllables.

With the subject G. in the smell-experiments, the value of *Wp* never actually exceeds 2.8, even for series of 41 and 81 members. Not all the series of 41 and 81 were ever mastered, but it is clear from the actual values of *Wr*, *Wp*, and *RS%* when $W = 1$, that all the series given could have been mastered in three or four repetitions, if the experimental sittings had been long enough. In the color experiments, the value of *Wp* never exceeds 3.3 except for series of 41 and 81. The three series of 81 which were ever perfectly reconstructed give a value of 6.0. At the outset, smell-series of 11 were correctly, though not perfectly, reconstructed with an average of 2.2 repetitions; at the end of the second year, when the subject's practice was at its maximum, series of 30 were correctly reconstructed with an average of 1.8, and perfectly reconstructed with an average of 2.2 repetitions. At the outset of the color-experiments *Wr*, with series of from 13 to 16 members, is 1.9 and $Wp = 2.1$.

The results of the other subjects show amply that these small

figures do not depend upon any peculiarity of G. Since 12 is a favorite series-length with the German investigators, let the reader look at the results for this length in the first period of Gr., and R. (Table III), of C. and N. (Table VI), and of the various beginners (Table V). Let him look also at the results of Wa. (Table II).

The very small number of repetitions necessary for memorising is the most striking peculiarity in our results. One may compare with the figures given the concise statement of Ebbinghaus: "Whereas I am able almost without exception to recite series of 6 nonsense-syllables without mistake after a single presentation, I can recite series of 12 syllables (read rapidly) only after from 14 to 16 repetitions, series of 16 only after 30, and series of 36 only after 55."[1] In the Müller and Schumann experiments, the average number of repetitions necessary to learn for the first time normal series of 12 syllables lies between 10 and 20. The Ebert and Meumann subjects at their maximal degree of practice learned series of 12 syllables by the ordinary procedure in the method of complete memorising with an average of 9.45 repetitions. This ordinary procedure is to read the series through, from beginning to end, with equal intervals between the syllables (the 'G-procedure'). Ebert and Meumann introduced three different variations into the procedure in reading. With the most favorable of these variations, at the maximal degree of practice, the subjects learned series of 12 with an average of 7.25 repetitions. One of the subjects, under these conditions learned with an average of 4.25 repetitions.[2]

Although the last figures quoted approach our own for the series length 12, yet when one examines the work of our subjects with series of 12 at the very outset of their work and looks, on the other hand, at their work on higher practice-levels with series of 20, 30 and 41 members, one is unavoidably impressed with the small number of repetitions required for learning the series.

b. The relative largeness of the mean variations is due to the

[1] *Grundzüge*, p. 651. Cf. *Ueber das Gedächtnis*, p. 64.
[2] Ebert and Meumann, *op. cit.*, pp. 134, 140, and 142.

relative smallness of the numbers averaged. If one averages 1, 1, 1, 1, and 2, one will get a mean value of 1.20 and a mean variation of .32 which is slightly over a fourth of the average. Yet numbers of repetitions cannot differ from one another by *less* than 1.

c. The number of repetitions required for a perfect reconstruction (Wp) is not greatly in excess of the number required for a merely correct reconstruction (Wr). When *Wr* is from 1.1 to 1.5, *Wp* never exceeds 1.9; when *Wr* is from 1.6 to 2.0, *Wp* exceeds 2.4 in only two cases; when *Wr* is from 2.1 to 2.5, *Wp* never exceeds 2.9; when *Wr* is from 2.5 to 2.9, *Wp* never exceeds 3.4; when *Wr* is from 3.0 to 3.3, *Wp* never exceeds 3.9. Very often the two values differ only by one or two tenths. Their approximation shows that the numbers averaged very often coincide, or, in other words, that series were very often reconstructed perfectly when they were first correctly reconstructed. In general, there is more divergence between the two sets of values in the color- than in the smell-experiments. Compare the results of G. in Table I with those in Table V, the massed results for smells with the massed results for colors in Table IV, and the smell-work of Gr. and R. in Table III with the parallel color-work of C. and N. in Table VI. The explanation of this greater divergence will be sought in the next chapter.

d. In all the sets of smell-series, with four exceptions, the subject G. learned upon the first presentation at least 60 per cent of the sequences. These four exceptions are the set of length 81, the first set of length 41, the set with the mean length 26.1 in Period II, 3 and the set with the mean length 23.2 in Period II, 2. That these last two cases are anomolous may be seen by looking at the results for *ML* 27.8 in Period II, 2, and for *ML* 23.2 in Period II, 1. In the second set of length 41, the percentage of right sequences on the first trial is 68.4.

e. The effect of practice is marked with both materials and with al the subjects except D. whose results are not so presented as to bring it out. To see the effect of practice in the ease of learning the same series-length in different periods, let the reader look again at the results of Gr. and R., Table III; of C. and N., Table

VI and of the beginners, Table IV. R., for example, was given 78 series of length 12. With the first 39, *RS*% (*W* = 1) was 59, *Wr* was 2.3 and *Wp* 2.4. With the second 39, *RS*% = 79, *Wr* = 1.5 and *Wp* = 1.6.

With G. practice is less evident with the colors than with the smells, and is obscured in passing from Period I, 2 to Period II, 1 by increase in the difficulty of the series.

f. In the case of the longer series practice affects the number of right sequences obtained at the first trial more than it affects the number of repetitions necessary to a correct reconstruction. See the smell-work of G., Table I, Periods III, 1 and 2, length 41; the color-work of G., Table V, Periods III, 2 and 3, lengths 41 and 81; the color-work of C., Table VI, Periods 3 and 4, lengths 21, 31, and 41; and the work of the beginners, Table IV, for the smell- and color-series of the length 18 as compared with those of the length 12. By 'the longer series' are meant series which are long for the practice-levels at which they are given. Neither the rule nor its reverse applies consistently in the case of the shorter series.

g. Within the limits of these experiments practice was unbounded in the direction of enabling the subject to memorise longer and longer series with a very few presentations. At the outset of the smell-work G. correctly reconstructed 71 series of length 11 with an average of 2.2 presentations; in the latter part of the third year, she reconstructed 13 series of the length 41 correctly with exactly the same average number of presentations. See also the work of D. Just how many presentations would have been necessary at the outset to enable G. and D. to learn series of 41 can now never be known. It simply did not occur to us to give them such long series at the outset. It would probably, however, have been impracticable to deal with such series in the limits of the longest possible experimental sittings. This fact is shown by the results of certain experiments upon beginners with series of the length 25. These results will be quoted in the next chapter.

The effect of practice in our experiments cannot be said to be greater or less than its effect in the experiments of Ebert and Meumann or of Fracker. Our experiments are not comparable

with these others. Ebert and Meumann tested the effect of practice in learning series of nonsense-syllables upon their subject's facility in learning a variety of material. This material was for the most part verbal but included series of meaningless characters (made, for example, by combining straight lines and semi-circles). The memory of the subjects was tested before, between, and after the two practice-periods. Fracker tested the effect of practice in learning the order of four tones upon his subjects' ability to memorise various kinds of material, some of it concrete but none of it olfactory. The reconstruction method was not used even with the concrete material. The order of the concrete series-members was stated by the subjects in verbal symbols, mostly numbers. The memory of the subjects was tested before and after the training-experiments The results both of Ebert and Meumann and of Fracker seem to show that facility acquired in learning one sort of material may be transferred to the learning of other kinds of material, whatever may be the nature of this facility and its physiological explanation. Our own experiments, on the other hand, were not originally designed to bring out the effect of practice, and the groups of experiments treated in this chapter did not happen to be so arranged as to bear at all upon the transfer of practice. The subject G. began the color-experiments a full year after the smell-experiments. She did not at the outset memorise the color-series as well as she had memorised the first smell-series, and never learned color-series as well as she could learn smell-series of the same length. However, this difficulty of the color-series for G. may have been so great as more than to cancel the effect of training with the smell-series. Hu. began to work with the colors three months later than with the smells. The subject had much difficulty in distinguishing the odors, and this fact is sufficient to explain her greater facility in learning the colors. None of the other subjects of these groups worked with both sorts of material.

h. The effect of practice is not evanescent. With G. the practice-level in the smell-work did not fall perceptibly during the summer vacation between Periods I, 4 and II, 1, nor during the two months pause between Periods II, 3 and II, 4. In fact,

the subject memorised considerably better in Period II, 4 than in Period II, 3 although the intervening pause was filled in part by a rather severe illness. The work of D., which is shown in Table III, was done after a pause of seven months. Yet it evidently is upon a high practice-level.[1]

i. In the direction of bringing longer and longer series well within the one-repetition span, the effect of practice is apparently not unbounded. For all series-lengths from 12 up, practice seems to end with reducing the value of *Wr* to 1 or 2 with some tenths. Even with the subject G., the lengths 12, 16 and 20 could never uniformly be memorised with one repetition.

j. On the higher practice-levels the difference in the numbers of repetitions necessary to the correct and to the perfect reconstruction of series of different lengths is less than proportional to the difference in length. See the work of G. with smell-and color-series of the lengths 41 and 81 in Tables I and V, the work of D. in Table III, and the work of C. and N. with color-series of 21, 31, and 41 in Table VI. On the lower practice-levels the differences in *Wr* and *Wp* are almost exactly proportional to difference in length. We find this relation in general maintained in the work of the beginners, Table IV.[2] However, in the first sets of smell-series, even in the work of the beginners, we find the difference in *Wr* and *Wp* less than proportional to the difference in length. This is probably because in this period the figures largely represent the work of the better memorisers. (The values of *N*, *Nr* and *Np* show that many series were never correctly or perfectly reconstructed.) The differences in *Wr* and *Wp* are never more than proportional to the difference in length except in those sets of experiments in which series differing in length, and long enough to create difficulty at the subject's practice-level, were given to the subject without announcement of their length. Such sets of experiments belong only to

[1] Upon the lastingness of the effect of practice, compare Ebert and Meumann, *op. cit.*, pp. 193–196. See also Müller and Schumann, *op. cit.*, p. 328.

[2] For example, in the first sets of color-series, *Wr* is 2.2 for length 12 and 3.4 for length 18. *Wp* is 2.6 for length 12 and 3.9 for length 18. The real lengths of the series to be learned were 11 and 17 respectively (see p. 47). We have, therefore, the following proportions: 11:17: : 1.00 : 1.55; 2.2: 3.4: : 1:00 : 1.55; 2.6 : 3.9 : : 1.00 : 1.50.

the first two years of the investigation (see pp. 70–71). Most instances of the disproportion under discussion are found in the work of G., Table I, Periods II, 1–3. The disproportion is, in all cases, very slight.

k. At all practice-levels, the subjects nearly always learned at the first presentation as many sequences out of the longer as out of the shorter series. This fact may be seen from the tables by comparing the percentages of right sequences for different lengths, at the same practice-level. The fact, however, can be brought out more clearly by figures which are not contained in the tables.

l. No exact correlation can be made out between the number of repetitions necessary to correct reconstruction (Wr) and the percentage of right sequences upon the first trial, (RS%, W = 1). When *Wr* is below 1.4, *RS%* (when *W* = 1) is never below 84 per cent and in the case of G. it is never below 88 per cent; when *Wr* is below 1.7, *RS%* is never below 75 per cent except in one set of experiments; when *Wr* is below 2.1, *RS%* is with one or two exceptions, never below 60 per cent. No closer relation can be observed. Striking instances of the lack of correlation may be seen in the work of D., Table III and C. and N., Table VI. For example in the work of D., for the length 31, *RS%* = 80.1 and *Wr* = 2.0, whereas for length 41, *RS%* = 64.7 and *Wr* again = 2.0. The lack of correlation is undoubtedly due in large measure to the fact that the subjects exerted themselves more upon the second trial when they knew that they had accomplished little at the first, whereas they were often reckless upon the second trial when they knew that they had virtually mastered the series upon the first.[1] When a number of repetitions is large, such variations of attention are of relatively little importance, but when the number is 2, 3, or 4, 'moral causes' may dislocate all the natural relations of the numerical results. Another reason for the lack of correlation will be suggested in the next section.

[1] Of course, the subjects were not told how well or ill they had done at each trial, but they themselves knew how far a given reconstruction had been a matter of guess-work.

At least upon the higher practice-levels, differences in series-length affect the numbers of sequences obtained in the first trial more than they affect the numbers of necessary repetitions. This fact shows that the learning process is not in general a very gradual one, or, in other words, that the values of *Wr* are not swelled by a large number of reconstructions of which each contains only a small amount of error. In this connection it may be remarked that practice does not consistently affect *Wp* more or less than it affects *Wr*.

B. Discussion of Results Not Represented in Tables I–VI.

The most important data which can be added to the information in the tables are as follows:

I. *There is no sharp and sudden limit to the length of the series which the subject can sometimes reconstruct correctly or perfectly after a single presentation.* This fact may be illustrated by the following statements: Some smell-series of the length 12 were given the subject G. upon nearly all of the higher practice-levels. Even in Period III, 1, she succeeded in reconstructing only 21 series out of 27 correctly and 19 out of 27 perfectly after one presentation.[1] Yet this same subject could often reconstruct much longer smell-series correctly and even perfectly at the first trial. For example, in Period II, 4 out of 32 series of lengths from 25 to 28, 13 were reconstructed correctly and 6 perfectly at the first trial. Out of 25 series of lengths from 29 to 32, 3 were reconstructed both correctly and perfectly at the first trial. In Period II, 5 out of 12 series of the lengths from 29 to 32, 3 were reconstructed correctly and 2 perfectly at the first trial. In Period III, 2 out of 14 series of the length 41, 2 were reconstructed correctly and 1 perfectly at the first trial. The subject D., out of 35 series of the length 31, reconstructed 9 correctly and 1 perfectly on the first trial. No other subject had sufficient practice to perform such feats as did G. and D. Nevertheless, the fact that any subjects could occasionally achieve them shows that our experiments deal with a kind of

[1] These results cannot be explained by a possible fall in the subject's practice-level during the summer vacation. Similar results were obtained with small groups of series of the lengths 12 and 16 in the middle of the second year.

memorising which is very different from learning to recite in succession rapidly presented nonsense-syllables.

II. *Subjects with no practice whatever can in general reproduce after a single presentation the serial order of not more than four smells and five colors, even when the initial unit is given.* This assertion is based upon the results of the last subgroup of experiments in the second and third groups. These experiments were made by a combination method, a cross between the memory-span method and our own reconstruction method. The subjects were given first longer and longer series and then shorter and shorter series. Each ascending and descending step was of one unit. Each series was presented but once, whether it was mastered at the first presentation or not. The results were massed, so that each 'case' in the statement given below is one series with one subject. The series used with the different subjects were for the most part the same, and were carefully arranged to avoid the presence of virtual duplicates in the same series and to secure a variety of units from series to series. As many series were given at a sitting as the time allowed. The subjects were beginners. In the color-experiments, the subjects numbered 43 and in the smell-experiments 35. In these two sets of subjects 26 were the same persons. The results are contained in the following table:

TABLE VII

Smell-Series

Subjects: Beginners. W = 1

L.....		3	4	5	6	7	8	9	9	8	7	6	5	4	3
N.....		35	35	35	35	35	35	35	35	35	35	35	35	35	35
Series correctly reconstructed	No.	34	28	14	14	7	6	2	3	3	5	12	27	23	35
	Per cent	97	80	40	40	20	17	6	9	9	14	34	77	66	100

TABLE VII—Continued

Color-Series

L.....		5	6	7	8	9	10	10	9	8	7	6	5
N.....		43	43	43	43	43	43	43	43	43	43	43	43
Series correctly reconstructed	No.	39	20	17	7	7	7	8	10	15	20	25	28*
	Per cent	91	47	40	16	16	16	19	23	35	47	58	65

*This result was due to haste at the end of the last experimental sitting.

In regard to these figures, it should at once be stated that the results for the longest series represent in general the work of different subjects and not of the same persons. Thus, the 21 cases obtained with the first color-series of 8, 9 and 10 members represent the work of 17 different subjects, and in no case did the same subject memorise all these series. In the light of this statement it is clear that the subjects did not come suddenly upon a limit to the number of smell-and color-units whose order they could memorise with a single presentation.

The figures have, farther, a twofold significance. In the first place they show that the number of color-and smell-units whose order could be memorised by unpracticed subjects with a single slow presentation was small in comparison with the numbers of nonsense-syllables, monosyllabic words and figures which educated adults can reproduce without special practice after a single rapid presentation. Ebbinghaus states the number of nonsense-syllables as 6 or 7, the number of monosyllabic words as 8 or 9 and the number of figures as from 10 to 12.[1] In the second place, the figures show that the effect of practice, in memorising the order of smells and colors slowly presented, must be enormous. Before practice the number of units whose order can in general be memorised by one presentation falls far short of the figures just quoted from Ebbinghaus. After practice, the case is violently reversed.

III. *The percentages of series in any given set which can be correctly and perfectly reproduced after one presentation—%SCR*

[1] Ebbinghaus, *Grundzüge*, pp. 649–650.

and %SPR—are correlated only in the roughest fashion with the numbers of repetitions necessary to correct and to perfect reconstruction (Wr and *Wp) and with the percentage of right sequences obtained upon the first trial, (RS%, W* = 1.). For example, we have such combinations as these below. The illustration is taken from the smell-work of G. in Period II, 4.

ML.	*N.*	*RS%, W* = 1.	*Wr.*	*Wp.*	*% SCR.*	*% SPR.*
19.3	12	93.4	1.3	1.9	83.3	50.0
23.6	26	81.8	1.8	1.9	34.6	30.8
26.6	32	76.2	1.8	2.4	40.6	18.8

IV. *The most frequent fault in reconstructions which were correct without being perfect was the changing about of series-members.* The placing-rules about 'making and leaving gaps' gave relatively little trouble even when the subjects were blindfolded. However, in the first two years of G.'s smell-work this error in placing was more common than transposition, a fact which shows that blindfolding was at first an appreciable handicap to this subject.

V. *The percentage of right positions obtained upon the first trial in general, but by no means always, exceeds the percentage of right sequences.* In the case of G., the positions are in excess in most sets of smell-series of the first year, in all sets of smell-series of the third year, and in all sets of color-series. In the smell-series of the second year, however, the sequences are very frequently in excess. In Period II, 3, for example, we have the following percentages:

ML.	*N.*	*RS%. W* = 1.	*RP%.*
15.3	12	91.8	92.4
19.0	21	79.9	79.6
22.8	21	77.0	75.9
26.1	11	43.5	39.5

These figures illustrate the small differences ordinarily found between the numbers of right sequences and right positions. However, even a small excess in sequences is noteworthy for the

reason stated on page 48. In the case of the other subjects, out of the sets of series included in the tables, the sequences are in excess of the positions only in seven altogether.

In general, when the series are relatively hard for the subject to learn, the positions tend considerably to exceed the sequences. For example, we find this relation in the longest color-series given to the subject G. (Table VI). In Period II, 2, *L* 41, *RS%* = 23.6 whereas *RP%* = 40.4; in the same period, *L* 81, *RS%* = 11.0 whereas *RP%* = 22.9; in Period II, 3, *L* 41, *RS%* = 30.7 whereas *RP%* = 43.3; in the same period, *L* 81, *RS%* = 11.3 whereas *RP%* = 31.3. In the smell-series of *L* 81 given to D., Period II, 2(Table III), *RS%* = 27.0 and *RP%* = 40.5. The positions also considerably exceed the sequences in the work of the beginners included in Table V. The excess is greater in the series of 18 than it is in the series of 12.

VI. *In general, the subjects tended to learn a larger absolute number of positions in the longer series*, although, as already noted, they tended to learn about the same absolute number of sequences out of series of different lengths. The most compact illustration of this fact is found in the following results which were obtained from the beginners:

Smells

Period.	*L.*	*N.*	Average Number per Series of	
			Sequences.	Positions.
1	12	88	4.7	5.7
1	18	91	4.6	6.1
2	12	44	7.5	8.5
2	18	39	8.4	9.8
		Colors		
1	12	118	5.5	6.4
1	18	118	5.6	6.9
2	12	105	7.6	8.5
2	18	105	7.5	9.5
3	12	72	8.3	8.9
3	18	72	8.6	10.9

VII. *The number of positions learned at the first presentation is not remarkably large*, small as is the number of repetitions necessary for complete memorising. We may fairly compare the massed results of our own fifteen beginners, for color-series of 18 members, with the massed results of the five subjects of Münsterberg and Bigham for color series of 20 members. The percentage of right positions for our subjects was 51.9 which implies a percentage of 48.1 in errors of position. The corresponding percentage of error for their subjects was only 28.4. Our series of 18 were really shorter by three units than their series of 20 (see page 47). Our colors were presented one to about every $3\frac{1}{2}$ seconds; theirs were presented one to every two seconds. It is impossible to tell from the report given just how many series composed entirely of colors were learned by each of their subjects. The experimenters sought 'to avoid any disturbance by mere training.'[1] The present writer traces the large excess of error on the part of our subjects to two causes. In the first place our color-series were much hard er to learn. Our series were drawn by lot from a set of 136 colors, many of them much alike. Münsterberg and Bigham used only 20 colors in all (so the writer infers) and could well afford to have them all easily distinguishable. In the second place our subjects learned enough series of the same kind to suffer from 'confusion,' as the effect of 'associative' and 'reproductive inhibition' is popularly called. Each of our subjects learned on the average $19\frac{2}{3}$ series of 18 colors and $19\frac{2}{3}$ series of 12 colors. The mutually counteracting effects of practice and inhibition will be discussed in the next chapter (page 137 squ.).

Briefly expressed, the most important general conclusion from the numerical results of this chapter is as follows: *We are dealing in our experiments with a form of memorising in which practice tends to reduce the number of necessary repetitions to the same number for longer and longer series. This number is surprisingly small.*

Our results in regard to series-length are diametrically opposed to the conclusions reached by Ebbinghaus with his

[1] Page 36.

differing material and method. The following passage is freely translated: "The alteration in one's ability to reproduce is surprising when the number of series-members exceeds even by a little the maximal number which one can just master with a single presentation. . . . . We should expect to find ourselves remembering about as many links as we can invariably memorise ('span, *umspannen*') in the case of shorter series, and forgetting the rest, but what we do find is that our incapacity for the greater performance damages our capacity for the smaller and that the number of members retained after a single presentation is greatly reduced. For example, out of series of even twelve nonsense-syllables, one can often repeat only the first and last members. Often in the case of longer series not even these members will 'adhere.' If the reproduction of the whole series is required, it is necessary to pile up the repetitions, and this number of repetitions needed increases with surprising rapidity as the series length increases." The figures quoted upon page 76 follow these statements. Ebbinghaus then adds the data obtained by Binet and Henri from the arithmetical prodigy Dimandi, who could learn 10 figures in 17 seconds, but required 2¼ minutes to learn 20, 25 minutes to learn 100, and 75 minutes to learn 200. In speaking of the limits of 'immediate memory,' Ebbinghaus remarks: "For the same individual under the same circumstances, the figures show a prettly sharp line of demarcation. I myself, for example, can perfectly reproduce 6 nonsense-syllables practically without exception, whereas I can only seldom succeed in repeating eight without mistakes. . . . . When bodily development is complete, the figures remain almost constant; in my case, they have not altered in more than 20 years."[1]

So far as the writer knows, the effect of series-length in memorising has scarcely been investigated apart from the individual study made by Ebbinghaus in *Ueber das Gedächtnis* and apart from experiments in immediate memory.

The respects in which our results differ from those of Ebbinghaus are three: In the first place the number of repetitions necessary to memorise did not increase with surprising rapidity as

[1] Ebbinghaus, *Grundzüge*, pp. 650–651.

the series-length increased. On the contrary, it increased with surprising slowness. In the second place, the subjects were in general able to remember after one presentation of the longer series quite as many sequences and rather more positions than they retained after one presentation of the shorter series. In the third place, there is no sharp limit to the length of the series which the subject can reproduce after a single presentation. Without anticipating the discussion of Chapter VI, it is evident that in our experiments we have nothing to do with the limits of immediate memory or with its span.

CHAPTER V.

THE MENTAL PROCESSES INVOLVED IN MEMORISING SERIAL ORDER.

The mental processes involved in memorising and in reproducing the serial order of smells and of colors presented slowly differ radically from the processes involved in memorising and reciting series of words and nonsense-syllables presented rapidly. This fact is evident from the statements of the last few pages. The purpose of this chapter is to scrutinise the mental processes of our subjects with the help of control-experiments and of introspective data.

It is at least theoretically possible that the peculiarities of our results were due to the concrete (non-verbal) nature of the material. The truth of this supposition has been rendered somewhat improbable by the work of other experimenters which seems to show that non-verbal material is relatively difficult to memorise. Münsterberg and Bigham found that the average percentage of error in the reconstruction of series of 20 colors was 28.4 as compared with a percentage of 18.0 in the reconstruction of series of numerals under the same experimental conditions.[1] Ebert and Meumann found that the learning of meaningless figures, such as combinations of dashes and semicircles, was much harder for their subjects than the learning of series of nonsense-syllables. On the first practice-level, 2.11 readings per syllable were required, on the average, for learning series of 12 nonsense-syllables and 3.83 exposures per figure for learning series of 12 figures. The corresponding figures for the second and third practice-levels were .83 and 2.33, .48 and .90.[2]

[1] *Op. cit.*, p. 37. For purposes of memorising, numbers may of course be considered as verbal material.

[2] Ebert and Meumann, *op. cit.*, pp. 48–49, 178 and 182. The *Erlerungsmethode*, not the reconstruction method, was used. The writers do not state exactly *how* the subjects were required to reproduce the marks. Verbal description, logical analysis, mnemonic devices, and drawing with the fingers were all forbidden in the learning.

None of these experiments bear upon the effect of differences in series-length. The experiments of Münsterberg and Bigham were not extensive and did not include a comparison of colors and nonsense-syllables with the same test-method.[1] Thus, we may be pardoned alike for making and for discussing our fourth group of experiments whose primary purpose was to test the relative difficulty of memorising the serial order of smells, colors and nonsense-syllables under the same conditions.

A. Numerical Results of Experiments in Memorising in Turn the Serial Order of Smells, Colors, and Nonsense-Syllables.

I. Tables of Results with Explanation and Discussion.

a. Tables VIII and IX.

See pages 92–93.

b. Explanation of Tables.

1. The abbreviations in these tables are precisely the same as those used in Tables I to VI (see pp. 59 and 66) with the addition of the abbreviation N.S. for nonsense-syllables.

2. The arrangement of the numerical data in the tables is also practically the same (cf. pp. 66–68), although the Roman numerals in the period-column for the subject G. in Table VIII require special comment. The experiments represented in the two tables were all made in the same year, 1904–1905, but this year was for G. the fourth year of the experiments with smell-material, the third year of the experiments with color-material, and the first year of experiments with nonsense-syllables. In the periods marked with the Arabic 1 the series-lengths massed were 14 and 16, on the one hand, and 19 and 20, on the other.

3. In explaining the tables, it remains only to give an account of the different subgroups of experiments: In Subgroup 1,

[1] In the later experiments of Bigham (Psych. Rev. i, pp. 453–461) colors and nonsense-syllables were brought into comparison, but the color-series were reconstructed and the syllable-series reproduced. It was easier to reconstruct the color-series than to reproduce the syllable-series.

TABLE VIII

Experiments of Group IV. Subgroup 1

SUBJECT.	MATERIAL.	PERIOD.	NUMBER OF *R S* POSSIBLE.	*ML*	*N*	*Nr*	*Wr*	*Np*	*Wp*	*RS* % *W* = 1	*ML*	*N*	*Nr*	*Wr*	*Np*	*Wp*	*RS* % *W* = 1
G.	Smells	IV, 1	401	14	**10**	9	1.8	9	2.0	81	19.9	**7**	7	1.7	6	2.3	76
	Colors	III, 1	433	14.2	**11**	11	1.3	10	1.6	86	19.9	**7**	7	2.1	7	2.1	65
	N. S.	I, 1	434	14.2	**11**	11	1.7	11	2.0	78	20	**7**	7	1.7	7	2.0	68
	Smells	IV, 2	520	41	**7**	4	2.3	4	2.3	74	81	**3**	0	.....	0	.....	27
	Colors	III, 2	480	41	**6**	5	2.8	2	3.0	39	81	**3**	0	.....	0	.....	8
	N. S.	I, 2	600	41	**9**	9	2.3	8	2.6	55	81	**3**	3	4.0	0	.....	27
Bo.	Smells	1	320	9	**12**	12	2.1	12	3.3	63	17	**12**	7	4.3	2	6.5	25
	Colors	1	320	9	**12**	12	1.5	12	2.2	80	17	**12**	12	3.9	12	4.5	35
	N. S.	1	320	9	**12**	12	2.0	12	2.4	65	17	**12**	12	2.7	12	3.2	37
	Smells	2	208	9	**6**	5	2.0	5	3.0	67	17	**10**	8	3.3	7	3.4	36
	Colors	2	416	17	**8**	8	2.4	8	3.1	45	33	**9**	7	5.0	5	6.2	13
	N. S.	2	416	17	**8**	7	2.3	7	2.6	32	33	**9**	7	3.9	6	4.3	15
Kl.	Smells	1	232	9	**7**	7	3.4	6	6.2	45	17	**7**	3	3.7	1	6.0	21
	Colors	1	237	9	**7**	7	1.4	7	1.9	77	17	**8**	8	2.3	8	2.4	56
	N. S.	1	237	9	**7**	7	1.6	7	1.9	77	17	**8**	8	2.4	8	2.9	48
	Smells	2	240	9	**10**	10	1.5	10	1.8	68	17	**10**	3	3.3	0	.....	28
	Colors	2	464	17	**9**	9	1.6	9	1.9	75	33	**10**	10	3.9	8	4.5	17
	N. S.	2	464	17	**9**	9	1.4	9	1.9	88	33	**10**	9	2.7	9	3.1	37
Wo.	Smells	1	210	9	**7**	7	1.3	7	1.6	91	17	**7**	7	2.0	7	2.1	52
	Colors	1	210	9	**7**	7	1.3	7	1.4	86	17	**7**	7	1.7	7	2.0	72
	N. S.	1	210	9	**7**	7	1.1	7	1.3	93	17	**7**	7	2.6	7	2.6	30

TABLE IX

Experiments of Group IV. Subgroup 2. *Subjects: 15 beginners*

MATERIAL.	PERIOD.	NUMBER OF *R S* POSSIBLE	*L*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1	*L*	*N*	*Nr*	*Wr*	*MV*	*Np*	*Wp*	*MV*	*R S* % *W* = 1
Smells.....	1	1132	12	**38**	26	3.5	1.4	23	3.4	1.4	28	18	**42**	15	4.0	1.3	15	4.1	1.3	19
Colors.....	1	1171	12	**40**	40	2.6	1.0	39	2.9	0.9	56	18	**43**	35	3.9	0.9	33	4.5	1.0	25
N. S.....	1	1177	12	**39**	34	2.5	0.9	33	2.7	0.9	54	18	**44**	44	3.5	1.1	40	3.8	1.2	31
Smells.....	2	481	12	**19**	13	1.8	0.6	12	2.0	0.6	50	18	**16**	13	2.7	0.6	12	2.8	0.4	42
Colors.....	2	543	12	**20**	20	1.7	0.9	19	1.9	0.9	73	18	**19**	19	2.7	0.7	19	3.2	0.7	46
N. S.....	2	543	12	**20**	20	2.0	0.9	19	1.9	0.8	72	18	**19**	19	2.8	0.6	18	2.9	0.7	44
Smells.....	1 and 2	1613	12	**57**	39	2.9	0.9	35	2.9	1.1	35	18	**58**	28	3.4	1.1	27	3.5	1.1	26
Colors.....	1 and 2	1714	12	**60**	60	2.3	1.0	58	2.6	1.2	62	18	**62**	54	3.5	1.3	52	4.0	1.3	32
N. S.....	1 and 2	1720	12	**59**	54	2.3	0.9	52	2.4	0.9	60	18	**63**	63	3.3	1.0	58	3.5	1.0	35

represented in Table VII, the subjects were G., Bo., Kl. and Wo. Bo. was a graduate student in a third-year course in psychology; Kl. was a graduate student in a second-year course, and Wo. an undergraduate in a second-year course. In Subgroup 2 both subjects and experimenters were beginners.

In the case of G., Bo., Kl. and Wo., the experiments extended from October to May, but were interrupted in G.'s case by control-experiments. G. served six times a week. As in the earlier work, two sittings were put together when series of 81 members were given. Bo., Kl. and Wo. worked each three or four times a week as subject and once a week as experimenter upon G. The beginners worked toward the end of the academic year and in general four times a week for four weeks. In the case of all the subjects, even of G., some of the work was done in the morning and some in the afternoon, but the hours were the same from week to week.

In Subgroup 1, the division of periods is according to the length of the series used. For example, in the case of Bo., the time during which series of 9 and 17 members were used in alternation with all three materials constitutes the first period. In Subgroup 2, the series of Period 1 includes the first three series of each kind given to each subject. Irregularities in the values of N are created by the throwing out of series. The massing of the beginner's work was done exactly as the massing was done in the third subgroups of Groups II and III. (Cf. p. 75.)

In Subgroup 1, the series of different lengths were given in a cyclic but not in a compensating order. The order prescribed was as follows: "shorter syllable-series, shorter color-series, shorter smell-series, longer syllable-series, longer color-series, longer smell-series, *and repeat.*" In Subgroup 2, the order was compensating as regards the arrangement of lengths, but merely cyclic as regards the arrangement of materials. The prescribed order was as follows:

a = *N.S.* 12, *C.* 12, *S.* 12
b = *N.S.* 18, *C.* 18, *S.* 18

a, b, b, a; b, a, a, b; b, a, a, b; a, b, b, a, and so on. (See page 45.) In both groups the regularity of the program was

somewhat broken by accident. The subjects knew the length of each series before it was given. As already stated (p. 24) the syllable-series were of the hit-or-miss variety.

C. Discussion of Results.

Conclusions which may be drawn from the tables are as follows:

1. *The serial order of the nonsense-syllables slowly presented is quite as easy to learn as the serial order of smells and colors slowly presented.* To the subject G., the color-series were distinctly harder than either of the other kinds. In learning the shorter series of smells and nonsense-syllables about the same number of repetitions was necessary, but upon the first presentation more smell-sequences were learned than syllable-sequences. Nevertheless, in the very few series of 81 which were given, the nonsense-syllables had distinctly the advantage.[1]

For the subject Bo. the smell-series were much the hardest; in the shortest series the colors had the advantage over the syllables, but in the longer series the syllables had, on the whole, the advantage over the colors. The case of Kl. was much the same. The smell-series were most difficult; the colors had somewhat the advantage among the shorter series; the syllables had decidedly the advantage among the longer series. With both Bo. and Kl. the results for the two sets of length 17 are inconsistent. The figures look as if with Bo. practice had more effect in the case of colors, and with Kl. more effect in the case of the syllables, but the numbers of series in the sets are so small that the difference may be accidental. In the case of Wo. there was much 'scattering' in the series-lengths given so that but few of the results obtained can be represented in the table. The results which do appear in the table were introduced to exhibit the exceptionally low values of *Wr* and *Wp* and the high values of *RS* obtained by this subject. Wo. was one of the subjects who showed greatest facility in memorising. To Wo., the smell-series after slight practice were distinctly the easiest,

[1] The nine series of 81 represent 18 experimental sittings. The series in each set are relatively few in this group of experiments because three different sorts of material were used.

although the table does not show this fact. Results which do illustrate it are these: Five series of 65 smells, 5 series of 65 syllables and 4 series of 65 colors were given. No values for *Wr* or *Wp* were obtained. The values of *RS*% (*W* = 1) were 23.1 for the smells, 6.6 for the colors and 6.3 for the syllables. Whether the colors or the syllables were harder for this subject cannot be decided.

The beginners, at the lower practice-level, found the smells much the most difficult material, and the syllables slightly harder than the colors. At the higher practice-level, the differences are remarkably small, except that among the shorter smell-series relatively few sequences were learned. *Wr* is, however, lower for the smells than for the syllables. Among the shorter series the colors are slightly the easiest; among the longer series the smells are perhaps slightly the easiest.

Inconsistent as these results seem, it is not impossible to interpret them. We may suppose that the material which best catches and holds the attention is easiest to memorise except in so far as the units are hard to discriminate. Smells have most intrinsic interest for some subjects; colors for others; syllables for none. The concrete series, moreover, present more variety than is presented by the syllables. Hence, in the case of the shorter series, in which relatively few difficulties of discrimination can in any case occur, either smells or colors tend to have the advantage. Smells, however, are much harder than colors for most untrained subjects to discriminate; hence, among the shorter series, the colors are generally left in the lead. It should be noted that G., the trained subject, has an exceptionally good discrimination for smells and an exceptionally poor discrimination for colors, when colors are presented in succession and at a considerable interval from one another. In the case of the longer series, on the other hand, those series are apt to take the lead which involve fewest difficulties in discrimination. Now, a color-series of any considerable length is sure to contain some units which are hard to discriminate. Hence, the longer the series, the more the syllables gain and the colors lose. The syllables, however hard to memorise, are always perfectly easy to identify ('tell apart'). Whether this

interpretation be valid or not, the fact remains that the numbers of repetitions necessary for the correct and perfect reconstruction of the syllable-series were of about the same magnitude as the number of repetitions required in the case of the smells and colors and that the slight fluctuation in the relative values was due to individual differences.

2. *With the new subjects practice had most effect in the smell experiments, and next in the color experiments, yet its effect in the syllable-experiments is marked.* The work of Kl. is an exception to this statement. Here practice had most effect in the case of the syllables and very little in the case of the longer smell-series. However, the number of series compared is very small. With all the subjects, improvement in the case of the smells is almost undoubtedly in large part an improvement in discrimination rather than in memorising.

3. *The results of G. seem to show that practice gained in the earlier experiments with smells and colors was transferred to the learning of the nonsense-syllables.* It is noteworthy that the three series of 81 syllables were all correctly reconstructed after the fourth presentation.

4. *In general, the syllable-series show, with increase in series-length, less increase in numbers of repetitions necessary to correct and to perfect reconstruction than is shown by either the smell-series or the color-series.* Taking the tables as a whole, it is evident that in the case of the easier series—i. e., of the series in which even the larger values of *Wr* and *Wp* are small—the difference in the values of *Wr* and *Wp* for different series-lengths is less than proportional to the difference in series-length, but that in the case of the harder series it is either roughly proportional or rather more than proportional.[1]

In general, in these experiments, difference in series-length made more difference in the numbers of necessary repetitions (both in *Wr* and *Wp*) than it made in the first three groups of experiments (the groups described in the last chapter). This

[1] The smell-series given to the beginners and to Kl. in the first period seem to constitute exceptions to the rule just stated. However, if one examines the values of N and Np one sees that the exceptions are of no importance. Evidently only the easiest of the longer series attained to correct reconstruction at all.

divergence in the results seems to be due to the fact that the subjects in the group of experiments with which we are now dealing had very little practice with any one sort of material. (This statement is not to be interpreted as telling against the transferability of practice except in so far as practice consists in the accurate sensing of the material to be memorised. Naturally, training in the discrimination of smells cannot be transferred to colors.) It is noticeable that it was precisely in the smell- and color-series, in which considerable training in discrimination is required, that the increase of difficulty with series-length was greatest.

5. *In general, the number of repetitions necessary to a perfect reconstruction approximates the number necessary to a merely correct reconstruction in the case of the nonsense-syllables rather more closely than in the case of the colors but scarcely more closely than in the case of the smells.* There is great irregularity in the relative values of *Wr* and *Wp*. On the whole, however, it is evident that the mere discrimination-difficulty in the case of the concrete material may be easily over-rated except as it may distract attention from the order of the links. For the sake of brevity a statement may be added here which is not derived from the tables and which, therefore, properly belongs in the next subsection. Correct reconstructions were reckoned imperfect on account of the transposition of members as often in the case of the syllables as in the cases of the smells and colors. This fact shows that such transpositions are in large part due to a tentative method of reconstructing the series and are not wholly due to mistakes in the identity of series-members.

6. *In this group of experiments the subjects, in many cases, learned on the first presentation a number of sequences out of the longer series which was smaller absolutely than the number learned out of the shorter series given at the same level.* This appears from the fact that the difference between the percentages of right sequences is often more than proportional to the difference in series-length. The disproportion does not hold for the sets of series which were easier for the individual subjects. Curiously enough, it does not hold for the sets of smell-series given to the beginners in either period. In the second

period, the difference is distinctly less than proportional to the difference in the length of the series. The ratios given on page 000 show that also in the smell-experiments upon the beginners in Group II the difference between the numbers of right sequences was, in the second period, less than proportional. This peculiarity in the smell-experiments may not be accidental.

II. Discussion of Results Not Represented in Tables VIII and IX.

The following conclusions may be drawn from data not included in the tables:

a. In every set of series, with three exceptions, the percentage of right positions obtained at the first trial exceeded the percentage of right sequences. The three exceptions are the smell-series of the lengths 14 and 81 learned by the subject G., and the color-series of 18 members learned by the beginners in the second period. The first two exceptions are of no importance owing to the small numbers of series in the sets and the slightness of the excess.

b. In the harder series, the excess of positions is much more marked than in the shorter.

c. In some cases, not quite so large an absolute number of positions was learned out of longer series given at any one practice-level as out of the shorter. (Compare pages 81 and 86.)

These last two conclusions and also the last conclusion of the preceding subsection (page 98) may be illustrated from the work of the beginners. The average number of sequences and positions learned per series were as follows:[1]

[1] The statements of the two preceding paragraphs are not illustrated as well by these figures as by the results of Bo. and Kl. These figures are chosen because the numbers of series represented are better worth considering.

Period.	*Material.*	*L.*	*N.*	*Sequences.*	*Positions.*
1	Smells	12	38	3.1	4.1
1	"	18	42	3.2	4.2
2	"	12	19	5.5	6.9
2	"	18	16	7.2	7.3
1	Colors	12	40	6.1	6.8
1	"	18	43	4.3	5.2
2	"	12	20	8.1	8.6
2	"	18	19	7.8	7.4
1	N.S.	12	39	5.9	6.2
1	"	18	44	5.3	6.0
2	"	12	20	8.0	8.2
2	"	18	19	7.5	7.9

As regards the conclusion lettered *b*, the figures show that the positions exceed the sequences (1) much more decidedly in the smell-series, ruling out those of length 18 in Period 2, than in the color-and syllable-series; (2) rather more in Period 1 than in Period 2, and in Period 1 rather more in the longer series than in the shorter. It may be seen from Table VI that the smell-series of length 18 given in Period 2 proved as easy as the color- and syllables-series of the same length. Therefore the smallness of the excess in positions is not surprising when the smells are compared with the colors and syllables. This small excess in positions in the case of the smell-series of length 18 and the actual deficit in positions in the case of the corresponding color-series of length 18 do, however, appear anomalous when the longer and the shorter series of this period are compared. In explanation, one can only say that irregularities must be expected when the numbers of series are so small and when the series themselves vary so much in difficulty. At least, the general trend of the first four groups of experiments is to show that the subjects grasped more at notions of absolute position whenever the task was hard, whether the difficulty was due to the material, to the length of the series, or to want of practice. Moreover, the results of the fifth group of experiments show beyond question that the tendency to learn 'by positions' was

no stronger in the case of the visible series at large than in the case of the smells.

One may now turn back to the work of the beginners for illustrations of the conclusions lettered *c* and of the last conclusion of the preceding subsection. One finds in the case of the longer color- and syllable-series as compared with the shorter, some falling off in the absolute number of sequences and positions learned. The drop, however, is very slight and affects the sequences more than the positions. It does not exist at all in the case of the smell-series (cf. page 99). It affects the colors much more than the nonsense-syllables.

It may be added that, in the results of the better trained subjects taken together, one finds a considerable number of instances where the sequences drop considerably with increase of series-length and yet the positions rise. For example, in the work of Bo., Period 1, in the 12 smell-series of length 9, 5.0 sequences and 5.8 positions were learned on the average, whereas in the 12 series of length 17, 3.9 sequences and 6.2 positions were learned. The results of the corresponding color-series are parallel. In the syllable-series, on the other hand, more sequences as well as more positions were learned in the longer series.

In brief, one may conclude from the statements of this section that as judged by their results the mental processes involved in memorising serial order are not essentially different, whether the material be smells, colors, or nonsense-syllables, primarily verbal or non-verbal.

This conclusion does not conflict with the findings of (1) Münsterberg and Bigham or of (2) Ebert and Meumann. (1) Münsterberg found numerals much easier to memorise than colors. But numerals are particularly easy to memorise on account of their tendency to combine into unit-groups and the ease with which they are apprehended. (2) Ebert and Meumann found meaningless combinations of lines harder to memorise than verbal material. But such figures are peculiarly hard to memorise for a reason which will be stated later. Here it is important to notice that the mere fact of being verbal

does not put the nonsense-syllables at a marked disadvantage nor give them a marked advantage over the concrete material.

B. Interpretation of the Numerical by the Introspective Results of the Reconstruction Method.

The purpose of this section is to interpret, as far as possible, the numerical results of the reconstruction experiments by means of the introspective observations which were made in connection with them. As a preliminary to the discussion of the introspective data, the writer wishes to make a specific classification of the kinds of associations which may coöperate in the memorising of series (or serial order). This classification may be schematised as follows:

ASSOCIATIONS.

A Primary = Principal (*Hauptassoziationen*).[1]
  I. Direct intrinsic.
    a. Progressive. b. Regressive.
  II. Extrinsic, viz: spatial or numerical associations.
B Secondary = Supplementary (*Nebenassoziationen*).[1]
  I. Indirect intrinsic ("criss-cross").
    a. Progressive. b. Regressive.
  II. Extrinsic, viz: auxiliary, mnemonic.
    a. Aids to attention. b. Aids to linkage.
C Representative associations.
  Extrinsic.

Principal associations are those in virtue of which taken alone (or merely with certain essential representative associations) the subject is able to reproduce the series in the manner required. When the test of mastery is the recitation of a series, in order, from beginning to end, then the only principal associations are those proceeding from each link to that next succeeding (the direct 'progressive' associations) and those running between

[1] The terms *Hauptassoziationen* and *Nebenassoziationen* are appropriated from Ebbinghaus. Cf. *Grundzüge*, p. 664.

each link and the idea of its absolute place in the series.[1] In the common form of the methods of right associates also, these two associations only can be considered primary. When, however, the test of knowing the series is the reconstruction of the order—when, strictly speaking, only mastery of the order is tested—then the associations running out from each link to the link next preceding, the direct regressive associations, are quite as important as the direct progressive. These three kinds of association, therefore —(I, *a*) the direct progressive, (I, *b*) the direct regressive, and (II) the associations running from the series-members to notions of absolute position and back again—will here be considered as principal or primary.[2] Associations between members of the series will be called *intrinsic* associations; associations which run outside the series will be called *extrinsic*.

Under supplementary associations are included (I) the associations between members of the series which are not in juxtaposition, the indirect intrinsic associations, and (II) the 'aids' (*Hilfen*) or auxiliary associations already mentioned. The auxiliary associations may be subdivided, according to Ephrussi,[3] into such associations with particular links as cause the attention to dwell on them singly,—'aids for the attention,'—and associations which serve as actual roundabout connections between members of the series—'aids to linkage.'

[1] Ebbinghaus considers only the direct progressive association, 'which far surpasses all others in strength,' as 'principal,' but according to the definition of principal associations given by the present writer, place or number associations must also be included, because it is theoretically possible for the subject to reproduce the series by attaching each unit to the corresponding number idea. (Of course, when it is said that these may be the only associations which come into play, the fact that the number ideas are themselves associated, two with one, three with two, and so on is disregarded.) Ephrussi considers the association of a link either with the link next following or with its place in the series as strictly mechanical memorising, i. e., as memorising without 'aids' of any sort. (*Op. cit.*, p. 16.)

[2] It is noteworthy that the position associations found in learning a series must function backward if they assist in reciting. If a subject says to himself *lig—three* in learning a series of syllables, he must say *three—lig* if the position notion helps him in recalling it.

[3] *Op. cit.*, p. 77. The aids or *Hilfen* are divided according to their effect into *Aufmerksamkeitshilfen* and *assoziative Hilfen*.

Representative associations are those which proceed from the members of the series to images which, in the subject's review of the series, are or may be substituted for the links themselves—which act as 'counters' for the links. In the case of the smells, such counters are absolutely necessary to memorising since, as we shall see, true smell-images are at best somewhat rare phenomena. The counters *are* the series in so far as the series is recalled, and since the counters are the series, the links between the counters themselves must be reckoned sometimes as principal and sometimes as supplementary, although the associations between the series-members and the counters themselves are representative. In memorising verbal material representative associations cannot be said to occur (unless indeed the visual, auditory, and kinæsthetic factors in the percept or image of a word be counted as three separate mental contents). The representative associations differ widely from the ordinary auxiliary associations in this way, that whereas the auxiliary associations seem to lapse, as the learning of the series progresses, yet some one representative image for each link persists and every link tends to acquire its own counter.[1]

Let us take, by way of illustration, a smell-series of which the first five members are rose, tar, caraway, ginger and almond. Then the associations directly connecting caraway with ginger, caraway with tar, and caraway with the word *three* are all primary whether the experiences of ginger, tar and caraway be smell-percepts, smell-images, word-images, or visual images of gingercake, tar-barrel, and sugared caraway seeds. The associations between the smell of caraway and either the word *caraway*, or the mental picture of pink, white, and yellow 'seeds' if so stereotyped as to serve as a symbol, are representative. The associations running from caraway to rose and from caraway, through the word or picture *cookie*, to ginger are supplementary. The cookie-association is auxiliary and is an aid to the linkage of caraway and ginger. An association of tar with images of a tar-spotted white pinafore and an angry mother may be an 'aid to attention.'

[1] See page 126.

The proper purpose of this half-chapter is the statement of the introspective data obtained in connection with the reconstruction experiments. This statement falls into two divisions. The first division bears mainly upon the subjects' method in memorising, and is based in large part upon written answers to specific questions. The second division contains an analysis, partly introspective and partly inferential, of the factors which determine the difficulty of memorising the three sorts of material. The introspective matter of this second section is furnished largely, though not wholly, by the writer, the subject G. Some of the more important statements of the subjects have been checked by sets of control-experiments. The results of these experiments will be given not by themselves in a separate section, but in direct connection with the introspective declarations upon which they bear.

I. The following are the chief points of interest in regard to the subjects' method of memorising: (*a*) the character of the images which represented the links in the series, (*b*) the kind of associations which bound together the links in the series, (*c*) the degree and manner in which the series-members were divided into unit-groups, and (*d*) the nature of the subjects' consciousness of practice. Lists of questions to be answered from introspection were issued to the subjects at or near the end of each series of experiments. In reporting the data thus obtained, the statements of G., the representative subject, will be noted first under each heading. It does not seem, in general, necessary to discuss the process of memorising apart from the process of reconstruction.

a. In the case of G., the images which represented the smells were in no case olfactory. Pictorial representatives—such as the visual image of a sprig of pennyroyal for the smell pennyroyal—were scanty and schematic. The smells were represented in a somewhat stereotyped fashion by their names (or by the names of other smells for which the subject mistook them.) G. had the advantage over all the other subjects in being able to name with considerable accuracy any smell in the list. For purposes of memorising, to be sure, it makes no

difference whether the smells are named properly or not, provided that the subject is contented with the names he gives, always names the same smells in the same way, and does not apply the same name to more smells than one. However, if the subject must depend largely on verbal images, a real poverty in names is a great handicap.

For G. every verbal image is highly composite, containing three elements, tactile, auditory and visual. The visual image is not, however, an image of a written or printed word, but is a color of synæsthetic origin. A color-image is so inherent in every verbal percept or image that it can scarcely be called an associated image in the ordinary sense. When a word is read, an auditory image, a kinæsthetic image, and a color-image fuse with the visual presentation. When a word is heard or remembered, only the auditory, kinæsthetic and color-elements are present. The color-image entirely displaces the proper visual image of the printed or written word which can be evoked only piece-meal, indistinctly and with difficulty. (This subject can never visualise more than one printed letter at a time.) The word-colors are consistent and well saturated, but are not sharply outlined or very nicely differentiated from one another, although they are sometimes parti-colored. Word-images which are the same in color are differentiated by their auditory and tactile elements. In some cases, the word-color of a smell-name is modified in actual dealing with the scent by the known color of the smell-substance. For example, the word *spearmint* is pink but the spot of color which stands for the smell is pink and green. In memorising, the importance of the color-images is this: The subject projected them into spatial relations so that 'in imagination' they formed a line or lines (see page 121) of ill-defined oblongs running from left to right, in the order of the series, either in a darkish space and at a convenient reading-level and distance from the subject's eyes,[1] or upon the

[1] When G. is in daylight and not blindfolded, the word-colors are not seen on a dark background, but they do usually seem to be seen at reading-distance and level. When the subject is actually reading, the colors flicker, as it were, about the written or printed letters and yet they do not seem to be on the paper. In reading black characters the word-colors are brought out vividly only by stress of attention to the sounds represented, but they are always present except when

vaguely imaged table. When the series was presented, the line of colors was gradually formed. In reconstructing the series, the subject read off fragments of the line of color-symbols with the aid of the auditory and tactile word-symbols, and represented the order with the bottles somewhat as a piano-player reads the notes 'with his fingers.' The comparison is rough, for the musician reads straight across the page, whereas G. read a fragment, now here now there, as the scents were taken up in chance order and suggested their neighbors. Only a small part of the line—a bit of the left part, right part, or center—was ever seen at one time. The subject's color imagery is vivid but is never complex. When questions of spacing were considered, the bottles themselves were imaged vaguely as standing in various places on the table, but, curiously enough, they were almost never imaged as having contents of different colors. They were often pictured as empty, and the space in which they were arranged was quite as clearly tactile as visual.

Two short series of experiments were made to control the subjects' assertions that she memorised the series in words, and largely by the aid of the name-colors. If these statements are true, then the serial order of the smell-names should be memorised at least as easily as the order of the smells themselves, and the order of words which are more highly colored than the smell-names should be memorised still more easily.

The first set of control-experiments was made in the spring of 1904. Three kinds of series were given: (1) series of smell-names, (2) series of English Christian names, and (3) series of words ending in the suffix *ation*. Of all words, such Christian names as have been familiar to the subject from childhood are most deeply colored. *Robert*, for example, is a full carmine

attention is focussed upon the actual black lines. The letter *S*, in so far as it consists of two curves, is black, but its sibilant sound is almost as saturated a salmon pink as a salmon pink geranium, though darker than the flower. Word-colors, however, for some unknown reason, are often quite different from the color of the component letters. *George*, for example, is the color of a heliotrope blossom although it contains not a single letter which verges on violet. With this subject pseudochromæsthesia was well developed in childhood and is undoubtedly hereditary. Word-colors never amount to actual hallucinations, but in fatigue colored hypnogogic phenomena are sometimes intrusive.

red and *Julia* is a lustrous purple. On the other hand, 'abstract' words, especially those acquired after early childhood, ordinarily have least color. *Unification*, for example, begins with a bright dash of green, but trails off practically into a dingy streak. Each list of words numbered 128, like the list of scents which was in use at just that time. The normal reconstruction method was employed. The words were written on the kind of cards used in the reconstruction experiments with nonsense-syllables. So many different series-lengths were used that it is impossible to present the results both precisely and compactly. Adopting the rough expedient of massing the results for the various series-lengths, we obtain the following values:

For the	*N.*	*Nr.*	*Wr.*	*MV.*	*Np.*	*Wp.*	*MV.*
Smell names.....	14	14	1.9	0.5	11	2.3	0.5
Christian names.....	9	9	1.2	0.3	7	1.4	0.5
Common nouns.....	9	8	1.5	0.5	7	1.9	0.2

The series-lengths were the same for the three kinds of words but ranged from 8 to 41.[1] Though the number of series is small, yet the figures seem worth giving because the mean variation is so very small in view of the variation in series-length. The experiments were, however, in a measure vitiated by the wealth of auxiliary associations which cropped up in connection with the nouns in *ation* and with the Christian names. Furthermore, as the subject herself planned the experiments, her attention was drawn strongly to the word-color, so that even the long common nouns with their uniform endings were pretty strongly colored. But at least the results of the experiments do not contradict the statement which they were designed to test.

The second lot of control-experiments, which was made in the spring of 1906, was combined with another lot whose purpose does not concern us here. Seven sets of experiments were made: (1) Experiments in which series of smells were presented and reconstructed in the ordinary manner with the subject

[1] In each of the nine lengths used one series of Christian names and one of proper names was given. In five of the nine lengths, two series of smell-names were given; in the other four, one only.

blindfolded; (2) experiments in which series of smells were presented and reconstructed in the ordinary way except for the removal of the eye-bandage; (3) experiments in which smell-names (on the ordinary cards) were presented and reconstructed; (4) experiments in which series of smells were presented in the ordinary way but reconstructed in terms of the name-cards as representatives; (5) experiments in which series of name-cards were presented, but in which the reconstruction was done in terms of the smells represented by the names; (6) experiments in which series of colors were presented and reconstructed in the ordinary way, and (7) experiments in which series of alternate colors and smells were presented and reconstructed. The last two kinds of experiments may, for the moment, be left out of account. The normal reconstruction method was used. The series-length was 41. We have the following values in the different sets of experiments:

For the	*N.*	*Nr.*	*Wr.*	*MV.*	*Np.*	*Wp.*	*MV.*
First set.....	3	1	2.0	.....	0	.....	.....
Second Set.....	3	3	2.3	0.4	2	2.0	0
Third set.....	3	3	2.3	0.4	2	2.5	0.5
Fourth set.....	3	3	2.0	0	3	2.0	0
Fifth set.....	3	3	2.3	0.4	1	2.0	.....

The length 41 was chosen that the values of *Wr* and *Wp* might be large enough to exhibit differences. Therefore, the number of series given was necessarily small, for two series could not be mastered at a sitting of three quarters of an hour.[1] With so small a number of series one can conclude from the figures merely that at the practice-level at which this subject had arrived, it made very little difference whether she was dealing with the actual scents or with their names.

In brief, one may conclude that G. memorised the smells in terms of representative images which were at once verbal and capable of a definite spatial arrangement.

[1]In explanation of the values of *Np* the reader is referred back to p. 67. This table illustrates the fact that when *Np* falls short of *Nr*, *Wp* may fall short of *Wr*.

G. remembered the colors mainly in the form of color-images. These images, however, were poorly differentiated and were eked out with color-words, which must be classed as representative images. Representative images, however, were much less important in the case of the colors than in the case of the smells. On the one hand they were less essential, and on the other they were less adequate. They were less essential because even in the case of G., whose color-discrimination is very poor, color-imagery is vastly better developed than is concrete smell-imagery. They were less adequate because popular color names are not sufficiently differentiated to describe 136 different colors and technical color-names are difficult to apply. The subject was perfectly familiar with the Milton Bradley system of names and symbols, but had too bad an absolute memory for color to make much use of it. 'It was easier,' wrote the subject, 'to try to remember the colors out and out than to think out names for them.' Concrete representative images scarcely occurred in the case of the colors. When a square of colored paper suggested the image of another object with the same color, this image was practically always an auxiliary image (*Hilfe*) and fell away as memorising proceeded to completion.

G. visualised the syllables as oblong spots of color. In the case of the smells, these color-images must be counted as representative, since they seem to have attached originally to the names and to have been transferred from the names to the smells themselves. On the other hand, the pseudochromæsthetic images of the syllables, however explicable genetically, must be considered as parts of the units of the series, not as extraneous additions. Their union with the visual presentations and with the unfailing auditory and tactile representations is by fusion, and not by association, except in the widest sense of that term.

The results obtained from the other subjects will now be presented. Fairly satisfactory introspective records are in existence for 45 out of the 46 beginners who made relatively extended experiments with smell-series,[1] including 19 beginners

[1] The memory-span experiments are not included. No introspective records were obtained in connection with them.

who experimented with mixed smell and color series in certain control experiments (see pages 142–144 below). Out of these 45 subjects, 18 explicitly disclaim ever having true smell-images; 6 describe the process of memorising without any reference to smell-images; 15 assert that they have true smell-images in the case of some few scents, either very familiar, such as peppermint, or very disagreeable, such as pyridin, but ascribe little importance in memorising to these images; and only 6 claim that they found smell-images distinctly serviceable in memorising. In regard to this claim the writer is extremely skeptical. This skepticism does not grow merely out of the disinclination which one has to believe in anything which is not a part of one's own experience. It is based partly on the results of certain control-experiments (not to be described here) which were made in connection with the questionary investigation mentioned on page 2, and partly on the fact that one of the most intelligent of just these six beginners makes a remark which discredits the claim in question. But whether this claim is based on sound introspection or not, it is significant that only 13.3 percent of the beginners ascribed much importance in memorising to smell-images. Of these 6 beginners only one claims that she memorised wholly in terms of olfactory images; 3 of the 6 acknowledge that they memorised the smells to some extent by names (or descriptive words) and 2 that they often thought of the smells in part by their numbers in the particular series. Among the 45 subjects considered, including these 6, 40 subjects memorised the smells more or less largely by name and 3 by number (using the series-numbers more or less as names). Only 1 subject used chiefly concrete visual images to represent the smells, but seven others report that concrete visual images were useful.

As to the adequacy of the names used, the following data may be presented: All the subjects were required at the end of the experiments to name the list of smells used, giving the name which they had used in the experiments if they could not give the right name. The following statistics refer only to the 83 selected scents referred to on page 15. The records of 18 representative subjects are considered, making a total of

1494 (18 × 83) attempts at naming. In 26.9 per cent out of the 1494 cases approximately the right name was applied; in 23.5 per cent a name not correct, yet the name of a smell really similar from the olfactory point of view (as e.g. *cloves* for *cassia*); in 21.6 per cent a correct class-name (as e. g. *spice* for *cloves*) or a descriptive adjective; in 3.9 per cent a name explicable by similarity of associations (as e. g. *ether* for *carbolic*), or of secondary concomitants (such as pungency); in 0.8 per cent a color-name perhaps indicative of pseudochromæsthesia; in 0.1 per cent the number on the bottle which indicated the material (and which must have been learned from the experimenter); in 14.9 per cent a name inexplicable by the writer; and only in 8.2 per cent no name at all.

All of the better trained subjects who have left satisfactory records claim to have memorised the smells mainly by name. No records exist for Ha., R. or Wa. All except He. and Hu. asserted that they sometimes had or 'could get' smell-images. Only Kl. (who memorised the smells very badly) claims that the images were an assistance in memorising the series. D., whose achievements have been noted on page 82, named about half the smells correctly.

Satisfactory records exist for 48 of the 49 beginners who made relatively extended experiments with color-series (or mixed smell- and color-series); of these 48 subjects 29 claim that they memorised the colors both in terms of concrete color images and of color words. Of these 29, 4 found the concrete imagery more important than the verbal, and 11 found the verbal imagery more important than the concrete, although 1 of these 11 remarks that this relation tended to be reversed with practice. Out of the 48 subjects considered in all, 12 report almost purely concrete and 7 almost purely verbal imagery. In one case the concrete imagery was largely representative. The subject purposely visualised trees, flowers, and shrubs as placed in a row to represent the colors.

Satisfactory records exist for only 6 out of the 8 better trained subjects who worked with colors. With C. and N. both verbal and concrete imagery were important. With C. the imagery became increasingly verbal. The imagery of Kl. was predomi-

nantly and the imagery of Bo. almost purely concrete. On the other hand, the imagery of Wo. was almost purely verbal.

The terms in which the syllables were remembered may be very briefly discussed. The images of the syllables were necessarily verbal, and this study is not concerned with the sense-type of verbal images, but merely with the existence of true olfactory images, and with the degree to which the concrete material was visualised in verbal terms. Of the 18 relatively untrained subjects, counting Bo., Kl. and Wo. with the 15 beginners, all except Bo. claim that they visualised the syllables. Three report imagery which was exclusively visual and 4 assert that the visual imagery was of paramount importance. Only Bo. and one other subject claim that auditory or tactile imagery was more important than visual. No synæsthetic imagery was reported.

It is impossible to correlate the character of the imagery with the facility of the different subjects in memorising. The amounts of practice vary too much in the different cases and other experimental conditions are too rough.[1] The point at issue here is simply the comparison of the images which represented the smells, colors and syllables. In view of the introspective reports as to the terms in which the three sorts of material were memorised, it is not at all surprising that the nonsense-syllables gave approximately the same results as the concrete material. *For, on the one hand, the concrete material was imaged largely in words, and on the other hand, the syllable-cards were quite as palpable as the color-squares.* Thus, the syllables were given a certain concreteness by the demands of the reconstruction method and became, as it were, names for cards which could be handled and laid in particular spots on the table. Nevertheless, some difference really exists between the processes of memorising the colors and the smells, on the one hand, and the syllables on the other. Neither the smells nor the colors are differentiated for any subject simply by their names. The experience

[1] The figures at their face-value seem to show that the subjects who depended most on concrete imagery learned worst. If this is true, it is, of course, because the concrete images are ill-differentiated.

which the subject lives through when a series of syllables is presented is, so to speak, single-strand as compared with the double-or triple-strand experience usually produced by a series of colors or smells. The smells themselves, as presented, form one strand, their names may form another, and the visual images of objects associated with them another. These second and third strands are entangled with one another and either may be broken but the one or the other is usually present. When the subject reviews the series, he follows these two subsidiary strands, and not the first, which for the most part slips from his grasp. If both the second and third strands break, he can as a rule, review the series no farther. In the case of the colors also most subjects have a fairly complete strand of names which is the more essential the worse the visual memory may be. Now this duplication of threads involves a disadvantage and an advantage. The disadvantage lies in the fact that until the names for the smells and colors have become stereotyped and the representative associations rapid, attention may be distracted from the connection of the links by the search for 'counters.' The advantage is that just in virtue of their representative associations the members of concrete series may be fringed with an extra set of aids. Carbolic and chloroform may as smells suggest the connecting link 'hospital' and the subject may also note the sequence of two initial *cs* in the names. Again the actual colors red-orange (almost a 'brick-red') and black would scarcely in themselves suggest 'Princeton' but the name-sequence might well do so. The writer is inclined to think that although the necessity of naming the smells and colors is a disadvantage to the untrained subject, the habit of noting *both* the series-member and its name is an advantage to the trained subject. It seems to the writer, from experience, that the peculiar difficulty of memorising meaningless characters lies in the facts (1) that the percepts are so purely—and, as it were, flatly—visual, without any auditory or kinæsthetic supplements (unless one is allowed to outline them with one's fingers) and (2) that compact verbal counters for them are hard to invent. On the other hand the writer believes that words, quite apart from the more artificial auxiliary associations and from

from their tendency to combine into groups, would be easier to memorise than nonsense syllables because with words so many concrete images go hand in hand. Here again the series-strand is double.

In brief, representative associations and complex images seem to be advantages in memorising. The smells and colors, however, had counterbalancing disadvantages which will be explained below.

b. In considering the manner in which the subjects linked together the members of the series, one should note particularly (1) the nature of the primary associations, and (2) the degree to which the subjects used auxiliary associations (*Hilfen*).

1. G. asserted that she 'memorised almost equally in terms of sequences and of positions.' The numerical results bear out this contention. (See page 85). As each series-member was presented, the subject made two or three closely successive but distinct efforts. She tried to visualise at least one sequence—i. e., the given member with its predecessor, and if possible in the later presentations, with its successor—and to visualise in connection with the given series-member either its number-word or its spot on the table or both. The efforts to visualise smell- and syllable-sequences were all directed toward word-color. To the auditory and tactile phases of the word-image little attention was consciously directed. The subject was distinctly conscious of the clinching together of series-members described on page 42 as a possible result of the slow rate of presentation. When a unit-group was visualised, one or two members would be clear and the rest slurred as if out of the visual focus. Except for occasional attempts to visualise a unit-group as a whole, G. did not review, between exposures, any sequence but the last. Attempts at reviewing while a presentation was in progress rarely paid, although the subject could sometimes safely anticipate sequences. The attention of this subject is of the stable type, and cannot be jerked from one content to another without a total break-down.[1]

[1] With this subject any attempt at immediate self-observation in memorising ends in prompt disaster, parallel to that of the centipede in the familiar rhyme.

Number-words were always important. G. paid no strict attention to counting the series-members one by one in words, yet she was always greatly disturbed by any conscious miscount, since wrong counting necessitated the redistribution of the series-members in the groups presently to be described. Moreover, the color of the number-word was often compared with the color of the paper-square or the color which represented a smell or syllable. Tansy is represented by a green spot. The word *nine* is green and the same color flickers about the Arabic (not the Roman!) symbol. Thus the occurrence of tansy in the ninth place could not escape observation.

In the earlier smell-experiments, G. did not systematically associate the smells with particular places on the table. As a methodical practice, the making of these table-associations for the smells developed at the end of Period II, 4 and distinguished Period II, 5 from this earlier period. (See page 73.) At the end of Period II, 4 the subject had been working with the colors, once a week, for about four months. From the first, she associated the colors (which she could see spread out before her in the process of reconstruction) with spots on the table. Probably, this method of spatial projection was transferred from the colors to the smells. At all events, the subject was conscious in Period II, 5 of a great increase in facility in memorising the smells, and ascribed this increase to her newly acquired system of attaching the smells as presented to images of the spots on the table where they should stand when placed by her in the order of presentation. Although the subject was blindfolded, the place associations were both tactile and visual. Her own median line was the line of orientation and any shift in her position was confusing, as she measured distances by reaches. The visual place-notions were schematic. The subject represented herself by a dark line. This system of spatial-projection, when once developed, was found useful, was carried throughout the smell-experiments and over into the reconstruction experiments with syllables, and has strongly affected the subject's procedure in memorising by other methods.

All the series were arranged by G. from left to right. If the series of smells exceeded 36 in number, the scent bottles in

excess were placed in a row behind the others, that is, farther away from the subject. The color-squares were arranged in rows of twelve and the syllable-cards in rows of twenty, the numbers which could lie without over-lapping in one row across the table used. In the case of the colors and syllables, however, the earlier members of the series were placed farther away from the subject than the later. This difference in arrangement between the smell series and the others was not made deliberately. Long series were used first in the case of the smells, and the length of the row was determined mainly by the subject's convenience in reaching the ends. When the series exceeded 36, it seemed 'natural to slip the extra bottles in behind the others.' On the other hand, it seemed equally 'natural' to this subject to arrange the series which she could see as the words run upon a printed page. When a book lies flat upon a table, the top lines of the page are farther away from the reader's body. This subject would not have been able to alter these arrangements without great, if temporary, confusion.

The subject G. claimed that she not only as a rule memorised the series-members themselves—in their nature or content, so to speak—*in learning* the order, but that she memorised them *in order to learn* the order. In the spring of 1905, at the end of the fourth group of experiments, control-experiments were made to test the subject's assertion that she memorised not merely the places but the nature of the series-members. Six sets of experiments were made, experiments of the first four sets in turn, and experiments of the last two sets later, in alternation. These experiments were as follows: (1) series of nonsense-syllables (hit-or-miss variety) were presented and reconstructed in the ordinary way; (2) series of nonsense-syllables were given in the ordinary way but were reproduced (not merely reconstructed) by the subject in order in writing; (3) series of smells were presented and reconstructed in the ordinary way; (4) series of smells were presented in the ordinary way but were named by the subject in order in writing; (5) series of nonsense-syllables were named to the subject at intervals of 5 seconds, and were reproduced in writing; (6) series of smells were named and reproduced in the same way. The series were all

of the length 41. In the written reproductions the subject was not limited as to time but any correction or interpolation was counted as equivalent to breaking a placing-rule. Thus in these series also a distinction was made between a merely correct and a perfect reproduction. We have the following values in the different kinds of experiments:

		For the	*N.*	*Nr.*	*Wr.*	*MV.*	*Np.*	*Wp.*	*MV.*
Presentation,	*Written*	(1) N.S. reconstructed.....	**14**	13	2.1	0.2	12	2.2	0.3
		(2) N.S. reproduced.....	**14**	11	2.7	0.5	9	2.8	0.5
		(3) Smells reconstructed.....	**13**	9	1.9	0.4	3	2.0	0
		(4) Smells reproduced.....	**13**	13	2.3	0.4	6	2.5	0.5
	Oral	(5) N.S. reproduced.....	**10**	10	3.0	0.2	7	3.0	0.3
		(6) Smells reproduced.....	**10**	10	2.1	0.2	8	2.1	0.2

These figures seem to bear out the subject's assertion. It was somewhat harder for her to reproduce the series verbally *in toto* than to reconstruct the order, but the difference in the numbers of repetitions necessary is surprisingly small. Reproducing the syllables was both absolutely and relatively harder than reproducing the smell-names, but this fact is entirely explicable by the difficulty of apprehending the syllables in such a way as to insure accurate images of them. It was especially hard to apprehend the syllables in the fifth set of experiments, not because the subject is dominantly eye-minded, but because the experimenters read badly. At this time, the subject had had almost no practice in memorising syllables except by the reconstruction method, and none of the experimenters had had practice in reading series aloud. It took longer to deal with the scent-bottles than with the syllable-cards; hence, the relatively small values of Np in the third and fourth sets of experiments.

Satisfactory introspective records exist for 41 different beginners who served as subjects in the reconstruction experiments, not counting the experiments with mixed series which must be considered apart as regards the matter now under discussion. Of these 41 subjects, 12 memorised almost exclusively by noting sequences, 18 almost exclusively by noting positions, and 11

by noting both or sometimes one and some times the other. Of these 11, 5 laid more stress on sequences and 3 on positions. Of the remaining 3, 2 memorised the syllables 'by sequence' and the smells 'by position,' 1 of the 2 memorising the colors by sequence and the other memorising them by position. Sixteen of the 29 subjects who memorised to a considerable extent 'by position' have left records as to terms of the position-idea. Six noted the numbers of the series-members, 8 associated the series-members with definite spots on the table, and 2 did both. Taking the beginners' records as a whole, one cannot maintain that the kind of primary association formed (sequence or position-number or place-association) depends upon the nature of the material used.

Of the better trained subjects who have left satisfactory records, F. and Hu. memorised almost entirely by sequence (learning in both cases 'a string' of smell names); E., He., Gr., C., and Bo. memorised almost entirely by position, and D., N., Kl., and Wo. memorised both by sequence and position. Associations with spots on the table were important to E., N. Kl. and Wo. Of these four subjects only Wo. showed marked facility in memorising.

One may make one remark in regard to the apparent advantages of the different methods. No subject who memorised concrete series-members by sequence only showed any facility in memorising. Learning by sequence only seems to be the poorest method. Perhaps one may hazard the conclusion that in the matter of sequences *versus* positions the eclectic method of G., D. and Wo. is the best.

Nearly all the subjects other than G. stated that they were accustomed to review the series, more or less, while a presentation was in progress. Reviewing seems to have been more common than anticipation. Some subjects who memorised by sequences seem to have proceeded in the style of 'This is the House that Jack Built.'

2. The subject G. did not use auxiliary associations systematically, but was accustomed to grasp at them in difficulties—especially if fatigued, confused or working under distraction. She was distinctly less dependent on them than were most of the

other subjects. These associations rarely amounted to the elaborate sentence- or story-type of mnemonic device and were more often aids to attention than aids to linkage. The only device used habitually was the assignment of certain smells and colors to stand for particular relatives and acquaintances. When the subject felt particularly well, happy, and 'detached,' auxiliary associations cropped up luxuriantly 'of their own accord' but accomplished little since, under these apparently favorable conditions, the subject was likely to place some of the units thoughtlessly. The criss-cross associations referred to on page 57 were especially important with G. on account of her method of grouping (see page 121 below).

In discussing the question of auxiliary associations, the records of the 19 beginners who worked with the mixed series may be added to those of the 41 beginners who worked with unmixed series. Of the 60 different beginners thus taken into account, 32 used auxiliary associations to a large extent and 26 to a very small extent, if at all. In other words, there were 53.3 per cent of 'ingenious' and 43.3 per cent of 'mechanical' memorisers. The other two subjects were among those who worked with all three sorts of material. One of them reports that she turned the syllables into sentences but used no 'aids' with the colors and smells. The other used aids with the colors, but not with the syllables and makes no report in regard to the smells. Good specimens of auxiliary associations are the connecting of black and pink by the 'red eyes of a mourner' and green and pale yellow by 'the green grass a hunting-dog runs over and the corn-meal mush he is fed on.' Considering that the series were presented very slowly and that the beginners were not forbidden to use these aids, the percentage which did use them does not seem large.

Of the better trained subjects only D., Gr., and Wo. appear from the records to have been of the ingenious type. The writer remembers, however, that the constant habit of Ha. was to connect the smell-names by a 'story.'

At the end of this discussion of the methods of linkage, it seems proper to sum up the answer to the question in regard to

the way in which the subjects occupied the relatively long intervals between the moment when they apprehended a series-member and the beginning of the next exposure. (See pages 11 and 42.) It has just been shown that the formation of auxiliary associations was by no means a universal habit. It has also been shown that G. was accustomed to note absolute positions and to image the sequences to which the last presented member belonged; if the member were *d* to image *c*—*d* and if the presentation were not the first to image or to try to image *d*—*e*. G. did not review earlier sequences; if she had any attention to spare she anticipated sequences. On the other hand, most of the other subjects did at least some reviewing while a presentation was in progress. This reviewing had two consequences. In the first place, criss-cross associations must have been strengthened by the dragging forward (so to speak) of earlier series-members into temporal juxtapositions with later ones. In the second place, each presentation of the series amounted to more than a single traversing of each sequence. The very worst inaccuracy of our method lies in the fact that we cannot determine just how many times a given sequence was traversed by a subject during any single presentation of the series. It seems probable that laborious reviewing is incompatible with the careful and complex clinching of sequences and of position-notions upon which G. relied. Examination of the introspective records seems to bear out this conjecture, but the data are too rough to be thrown into statistical form.

c. From almost the beginning of the experiments, the subject G. grouped the series-units in fours. (She had long been accustomed to count by fours any sort of units in a row.) In the case of the smells, not only were the first and second and the third and fourth units paired off by rapid visualization, but often also the first and fourth and the second and third, a pairing which reminded the subject continually of the means and extremes of an arithmetical proportion. The effort to see the group-units as 'wholes' often consisted just in this rapid pairing. In the case of long smell- and color-series, these group-units of four were united into lines of twelve which seemed to

constitute natural divisions of the series each with 'a center and two wings.' In the lines of color-spots which represented all three sorts of series there were no blank spaces between groups. The subject seemed to herself to group the images by the kind of broken eye-movement which, in counting, groups the stitches in a row of plain knitting or the palings in a fence.

Of the 41 different beginners who served as subjects in the experiments with unmixed series, 24 claim that they broke up the series into unit-groups of uniform length (or of uniform length as far as the total series-length permitted). Of these 24, the writer believes that some half dozen misunderstood the question. (See, moreover, page 128 below on the doubtful spontaneity of the grouping in many cases.) Five subjects deny that they did any grouping at all. The other 12 report the habitual selection of certain striking members of the series as 'pillars' or landmarks and the attaching of other members to these supports or centers.

Of the better trained subjects all but D. and C. formed unit-groups of the same length. D. and C. grouped by setting up landmarks at certain fixed positions in the series. D., for example, divided her series into rows of 10, and attached the second and third units to the first, the fourth, sixth and seventh to the fifth, the eighth to the seventh and the ninth to the tenth. With the majority of all the subjects, the length of the even unit-groups was four, but three was also a common length. The even division of the series seems to answer to rhythmical reading in the method of complete memorising; the landmark method of grouping does not.[1]

[1] The writer has examined a considerable number of records (including her own) to determine whether or not the subjects' habits of grouping left unmistakable traces upon the numerical results. This is not the case. It would be impossible to guess at the size of the unit-groups from any accumulation of errors at particular points in the series as reconstructed. This hiding of the lines of cleavage between the groups may be due to the heterogeneous character of the material (see page 141) which introduces special difficulties at different points in different series, or it may be due to the special effort which the subjects made to join the unit-groups securely one to another.

The results show that the subjects tended, like subjects in the method of complete memorising, to learn the series from the two ends toward the middle and more rapidly from the beginning than from the end. This tendency, however, is

d. Ebert and Meumann analyse the practice acquired in memorising meaningless material into the following factors (the order is that of the present writer): (*a*) Habit of rhythmical reading; (*b*) increasing keenness of apprehension; (*c*) increasing stability of attention; (*d*) increasing economy in the application of attention; (*e*) change in the affective tone of the learning-process from unpleasant to pleasant; (*f*) change in the organic sensations connected with it and in its motor accompaniments,—particularly the lapsing of unnecessary muscular contractions; (*g*) increasing complexity in the images which represent the series-members,—so, for example, that the eye-minded subject becomes ear-minded and lip-minded as well; and (*h*) the subsidence of the tendency to catch at extrinsic associations,—even of those between the series-members and the notions of their absolute positions in the series.[1] Before practice, consciousness (*Bewusstsein*) is like a scatter-brained commander who brings up all sorts of auxiliary troups which afterwards prove superfluous. With practice, the learning process becomes simpler. Consciousness takes the most direct means and discards secondary measures. Learning becomes ever more 'mechanical.'

Fracker holds that the development and the consistent use of one's own imagery is 'the central or most essential element'

not marked because the series were learned *in toto* with so small a number of repetitions. Rather less than half of the subjects specifically questioned noted that they had purposely paid special attentions at one presentation to certain fragments of the series and at other presentations to others. This practice was called among us piecemeal (*stückweise*) learning. It is hard to draw the line between the learning of the series in disconnected parts, on the one hand—a practice which is certainly disadvantageous—and the economical distribution of attention, on the other hand—a knack which comes with training and is essential to rapid learning. Probably in so far as our subjects, including G., indulged in piecemeal learning, the practice was serviceable.

[1] Ebert and Meumann, *op. cit.*, (a) and (b), pp. 204 and 213; (c) and (d), 204; (e), 215–216; (f), 202–203 and 215; (g), 204 and 228; (h), 204–215. The writers say (p. 215) that the central factor in practice is to be regarded as a will-phenomenon, since without the will to improve no progress is possible. In the opinion of the present writer such a will-phenomenon is altogether disparate from the factors enumerated in the text and need not enter into this discussion. Ebert and Meumann speak—whether carelessly or with intention—of pleasure as both an index to increase of psychological energy and as a factor in producing it (p. 216).

in improvement in memorising and in the transference of practice from one material to another.[1] The kind of imagery meant is in large part that which is called by the present writer *representative*. Coover and Angell find the essential elements of practice in the steadying and economical distribution of attention and in the 'habit of stripping the essential process of unnecessary and complicating accessories.'[2] Upon the importance of this last point all these students of practice and its transfer agree.

In dealing with the statements of our own subjects, the experience of G. will as, heretofore, first be detailed; and later, the fragmentary remarks of the other subjects will be summarised.

1. Before discussing the nature of the training which G. acquired in these experiments, it is necessary to note the practice-level at which she began. This subject had in childhood a verbal memory which was somewhat extraordinary, and as a result she was often 'shown off' by her parents when three or four years old, and later, in school-exhibitions. She thus acquired a certain vanity in regard to memorising feats. Hearing (at twelve or thirteen) that children in the mission schools of China often learn the whole of the New Testament *verbatim*, G. emulously set out to do likewise, began valiantly and successfully with the genealogy in the first chapter and actually learned considerable portions of the Gospels and Epistles. As a Sophomore in college she found Loisette's memory-system an absurdly round-about and laborious procedure. She was at this time (in her nineteenth year) conscious of habitually memorising almost without auxiliary associations. A year or two after graduation, during recovery from a tedious illness she learned "In Memoriam" *in toto*. Some years later, tests in the Cornell laboratory showed that she retained a facility in

[1] *Op. cit.* pp. 94–97 and 101.

[2] Coover and Angell, *General Practice Effect of Special Exercise*, Am. Jour. Psych., xviii, pp. 328–340, especially p. 340. Cf. also J. R. Angell, *The Doctrine of Formal Discipline in the Light of the Principles of General Psychology*, Supplement to University of Michigan Bulletin, New Series, ix, No. 8, especially pp. 9, 10 and 13.

memorising which was certainly above the average.[1] It is impossible to compare G. with the other subject of these experiments. Her case must stand alone both on account of the degree of her previous training and on account of the overtaxing of her memory during the experiments themselves—a burdening which sometimes seemed actually to paralyse her memory by anticipatory ('associative' or 'generative') inhibition.[2]

The factors in practice which are specified by Ebert and Meumann will be taken up severally, and after them, that development of representative imagery which is emphasised by Fracker.

(*a*) Rhythmical reading in the method of complete memorising finds in our method its counterpart in grouping. With G. elaboration of grouping was one of the very most important factors in practice. The system of grouping in fours developed soon after the beginning of the experiments. In Period II, 2, of the smell-work, when very long series (of 30 members and over) were first given (see page 73), the subject began to group more elaborately and to pay sharp attention to joining the initial and terminal members of groups, and to binding the terminal unit of each group to the initial unit of the next. Learning to cope with longer and longer series seemed tantamount to learning to group in a more and more complex fashion, e.g. to bind three groups of four smells into a larger group of 12, and five groups of four syllables into a larger group of twenty. Sudden increase in series-length seemed to produce a certain shock which would break up even the first groups of series-members. The surmounting of this shock seemed to lie just in the recovered ability to group.

(*b*) The subject was not conscious of any improvement in apprehension except in the case of the nonsense-syllables where

[1] See S. E. Sharp: *Individual Psychology*, Am. Jour. Psych., x, pp. 32–42, especially Table VI. The G. of these experiments was the person here under discussion. Other experiments made in the same year showed that G.'s discrimination for color- and brightness-differences was exceptionally poor. See I. M. Bentley: *The Fidelity of the Memorial Image*, same Journal, xi, pp. 37–38.

[2] See note p. 137, below.

it was well-marked. She was familiar with the smells when the experiments began.

(*c*) and (*d*) The subject was clearly conscious of learning to save her 'energy,'—i.e. her high degree attention—after the first presentation, for those units which she had not yet grasped and linked, and in particular for the joining of the unit-groups. She was not conscious of learning to control her attention better but only of learning to distribute it better.

(*e*) On the whole the subject always enjoyed the experiments, much as an enthusiastic player enjoys a bridge-party in spite of the bad hands he may get and the mistakes he may make in the course of the evening. Ennui never sets in. Since the task of memorising always had intrinsic interest, no great improvement in attention could be expected.

(*f*) The subject did not in the reconstruction experiments detect in herself superfluous innervations. However, in the longer smell-series the double effort to remember the series-order and the contents of the bottles already placed was often so exhausting as to produce muscular tremor, disagreeable chest-sensations and even slight nausea (symptoms which did not immediately pass away). The subject never had these feelings when dealing with the visible series.

(*g*) The direct images of the series-members did not appear to become more definite or more complex. The subject did not, to any marked degree, improve in color discrimination; she did not gain at all in ability to image the forms of the letters in the syllables; and she never acquired any concrete smell-imagery.

(*h*) The degree to which the subject used auxiliary associations was not a matter of practice. She had very long passed the stages at which they are first eagerly invented and then dropped. As already stated, (page 119) she was accustomed in difficulties to fall back upon them as a reserve force but she never went much out of her way to summon them.

(*i*) The subject had, from the first, a pretty complete system of representative images for the concrete series-members and was not conscious of much development in this particular. She agrees with Fracker (apparently as against Coover and

Angell, who appear to make no distinction between mnemonic and representative images) that these images do not fall away with practice but remain a *sine qua non* in the successful memorising at least of concrete material.

(*j*) One more factor in G.'s practice remains to be noted: This is the growth and persistence of spatial associations (here classed as primary).[1] Ebert and Meumann found that the tendency to grasp at position-associations fell away with practice. In our experiments, however, the habit of forming spatial associations was fostered by the reconstruction of the series in external space and by the slow rate of presentation. The subject G. believes that she was enabled to perform the feats described on page 184 of the next chapter just by this practice in forming spatial associations together with the practice obtained in grouping. *With G. 'spatial projection' and grouping were the essentials of practice.*

In the case of this subject the mechanising with practice of the memorising-process was more marked than its simplification. G. never in these experiments (never, within her recollection, in any memorising) made useless muscular contractions or employed many auxiliary associations. Therefore, at the start, the learning process was relatively simple. On the other hand, G. noted to the last (almost as this page goes to press) both the sequences and the absolute position of the series-members and sometimes noted the position both in terms of a number-word and of an imaged table-spot. It is impossible to say that she always noted with equal clearness both the sequence and the position of every series-member. Probably she did not. The whole process is very rapid, and introspection is fatal to its taking a natural course.

2. The subjects other than G. were not all questioned in regard to the consciousness of practice. Of those who were questioned, many expressly deny that their method of memorising changed. Several subjects instance grouping and several instance the forming of auxiliary associations as factors in practice. In the

[1] Notions of absolute position in the series (see p. 4) may or may not be images of places on a table or a sheet of paper, but for G. in all the later experiments the most important notions of position were spatial.

case of some of the beginners both these procedures received a certain impetus from a class-discussion which took place during the course of the experiments.[1] Two or three of the subjects, note that in the case of the color-series the imagery became more concrete and direct with practice. Wo. notes that although in placing a color or smell it was necessary at first to recall its name, yet afterwards the name-link between the concrete impression and the notion of position tended to drop out. On the other hand, C., who like Wo. memorised readily, notes that the images which represented the colors tended to become more verbal as her color-terminology improved. A number of subjects remarked toward the end of the experiments that at first they 'had not known how' to learn the series. When asked in what 'learning how' had consisted, the subjects usually instanced either the naming of the smells and colors, or 'getting used to' (learning to apprehend) the smells or syllables, or learning 'to tell the smells apart,' or grouping or piece-meal (stückweise) learning, or more than one of these factors. No factors which fall under the general head of the 'effort-consciousness' were spontaneously mentioned.

II. The purpose of the paragraphs immediately following is to enumerate and, in part upon an experimental basis, to discuss certain differences between the three kinds of material. In this discussion, the primary difference between verbal and non-verbal material is not included. The differences which will be considered lie (*a*) in the ease with which members of the three kinds of series are apprehended—their *Geläufigkeit*, (*b*) in the ease with which they are distinguished from one another, (*c*) in their attention-value or *Eindringlichkeit*, (*d*) in their richness in earlier associations, (*e*) in their homogeneity, (*f*) in the degree to which the difficulty of the series depends upon

[1] Experiments with beginners must be mainly demonstrative in purpose. In so far as the experiments are an humble kind of research, such discussions are unfortunate. Nevertheless, a certain artificial raising of the practice-level in the case of the beginners does not derange the argument of this report. As regards practice, the writer is not trying to prove that 'innate retentiveness' may be bettered, but is merely trying to show how much more one can accomplish with a better technique, however acquired.

the order of the members, and (*g*) in the fact that the colors and syllables are visible and the smells invisible.

a. Some pains must be taken to explain just what is meant by difference in the ease with which the members of a series are apprehended.[1] The ease with which a smell is apprehended depends in part upon its intensity and in part upon its familiarity but is not wholly determined by either or both. Anise—named paregoric by the subjects at large—is a strong and familiar smell, but is nevertheless apt to give pause for an instant to the best observers. The third factor in determining the ease with which a smell is apprehended seems to be its relative uniformity under different conditions. Some smells, notably the artificial perfumes, are liable to perversion through the exhaustion of the subject's sense-organ; others, notably the essential oil of anise, smell different at different temperatures. The 'apprehensibility' of a smell does not depend upon its distinguishableness from other scents. Eucalyptus and rosemary are very liable to be taken for each other, but neither perplexes the subject unless the other is in the series. Anise, on the other hand, has no 'twin' on the list. The ease with

[1] The verb *apprehend* is used as the equivalent of the German verb *auffassen* and differs in meaning from the verb *perceive*, in its ordinary sense, as *auffassen* differs from *vernehmen*. To apprehend is to perceive in the completest fashion—in such wise that the mere peripheral experience receives associative supplements, sensory or motor or both. To apprehend an object it is not necessary to name it. Nevertheless the naming of a scent, like the pronunciation of a written word, is the seal and attestation of apprehension. The difference in the ease with which members of series are apprehended is one of the most important differences between materials for memorising and is a difference to which, so far, scant justice has been done. Frl. Ephrussi says in regard to her experimental comparison of the relative advantages of 'Lesen im ganzen' and 'Lesen mit gehäuften Widerholungen': "Die Gesichtspunkte, zu denen die bisherigen Untersuchungen über die 'Oekonomik des Lernens geführt haben, liefen darauf hinaus, dass sie betonten, es sei das Lernverfahren so zu gestalten, dass die Assoziationen gemäss ihrer Abhängigheit von der Wiederholungszahl und der Art ihrer zeitlichen Verteilung möchligst günstig ausfielen. Meine Versuchsergebnisse zeigen, dass die Assoziationsstärke, welche unter bestimmten Umständen erzielt ist, zugleich auch von der Geläufigkeit der zu assoziierenden Vorstellungen abhängt in dem Sinne, dass mit der grösseren Geläufigkeit des Lernmaterials die grössere Assoziierbarkeit verbunden ist." (*Op. cit.*, pp. 61–62). Incidentally, however, relative familiarity had already been recognized as affecting the degree of difficulty in memorising nonsense-syllables. Cf. Ebbinghaus, *Ueber das Gedächtnis*, pp. 134–135; and Müller and Schumann, *op. cit.*, p 176.

which a color is apprehended depends mainly on its saturation, and this is at least in part because the grays and the less saturated color are more liable to momentary perversion through contrast-effects than are the more saturated colors. The ease with which a syllable is apprehended seems to depend primarily upon its resemblance to words which the subject is accustomed to reading or hearing. Differences in the ease with which the subject pronounces certain letters may also come into play. When the syllables were presented to the eye, G. had difficulty in 'grasping' those with a final *r*, *f*, or *th* sound, and those containing the vowel *o* when the final consonant was not followed by the silent *e*. Among German syllables, she has trouble with those containing *o*, *u*, *ö*, and *ü*. Such difficulties would seem to depend upon relative effort or uncertainty in pronunciation. For example, the sound ordinarily, if not correctly, given by Americans to *o* in the word *dog* is totally different from the sound of *o* in the word *dot*. When the syllable is meaningless there may be slight hesitation as to which precedent to follow. The hesitancy which G. had already experienced in earlier experiments with nonsense-syllables, led in these experiments to the use of the silent *e* to minimise the difficulty in reading.

The subject G., at least, grasped both the smells and colors more slowly than the syllables. A certain evasiveness seems to be a direct consequence of the simplicity of the colors and smells. This evasiveness, however, does not imply greater variation in 'apprehensibility' than is shown by the syllables. Undoubtedly, G. 'grasped' the smells more easily from the beginning than did most of the other subjects. It seems pretty safe to say that for all the subjects 'syllables, colors, smells' is the order of *Geläufigkeit* or 'apprehensibility' but that the degree of difference is a matter of individuality.

b. As regards sensible discrimination, G. had most difficulty with the color-units. The majority of the other subjects had most trouble with the smells. The writer is inclined to think that in their case the trouble in discrimination was rooted in the trouble in apprehension. The untrained subjects com-

plained repeatedly that 'that all the smells were just alike' except for a few 'very bad' ones, and sometimes that the smells were 'intangible,' or 'impossible' to 'get hold of.' But as a matter of fact there was much more objective excuse for confusing colors than for confusing smells. It will be remembered that the formation of the smell-series was not left absolutely to chance, but that certain highly similar smells might not be introduced into the same series. The writer has spent much time to little purpose in studying the cases in which each of two smells or colors was put in the place of the other. This examination throws no light upon questions of smell-classification. It does, however, show first, that the colors, much more often than the smells, were transposed from confusion due to real similarity, and second, that only a minority of the cases in which two smells were transposed can be explained by similarity of any sort. The following statement will illustrate the nature of the smell-transpositions: Any transposition of two series-members may be due to accident. When, however, a reconstruction is not the subject's first attempt at rearranging the series and when this reconstruction is right except for a single transposition, the presumption is at its maximum that the transposition is due to confusion. Under these conditions, asafœtida and some other smell were transposed 20 times. In two cases only this other smell was really a similar one—in one case onion, and in the other fish-glue. In four cases the other smell was also very unpleasant; twice it was valerian and twice pyridin. Once the other smell was eucalyptus, once rosemary, once cinnamon, twice ginger, once bay-rum, once spearmint, once sassafras, once cocoa-butter, once lavendar, once almond, once tar, once naphtholine and once kerosene. This sample shows how little in regard to the qualitative kinship of smells can be gleaned from the results of beginners. The sample also bears out the conjecture that difficulty in smell discrimination may be largely a matter of having very vague but highly affective smell percepts.

'Syllables, then colors or smells' was the order of 'discriminability.' Difficulties in discrimination and apprehension put the colors and smells at a very decided disadvantage as com-

pared with the syllables. There is very little difficulty in discriminating the syllables when properly apprehended or 'read.' Like syllables, to be sure, are sometimes confused when a series is very imperfectly memorised, but like colors are often confused in reconstructions which are otherwise perfect. Hence, the divergence between the values of *Wp* and *Wr* in the color-series. (See pages 77 and 98.) Nevertheless, there is no great difference in the difficulty of memorising the three sorts of material. Therefore, one of the two following alternatives must be true: either the concrete materials have certain counterbalancing advantages over the syllables, or else memorising by the reconstruction method is so easy that the nature of the units makes very little difference.

When the units of a series are hard to apprehend or hard to discriminate from one another, the learning of the series is made more difficult in two ways. In the first place, the subject is likely not to secure a series of definite and well differentiated images. In the second place, attention is so taken up by each link as it comes that there is none left over for the sequences or for notions of position. G. was very frequently conscious of this fact, and when working with long series, was often conscious during the first presentation of 'trying to find out just what colors, syllables or smells were in the series and of letting the order go.' The numerical results show that other subjects besides G. practiced this particular economy of attention. In the case of the easier series, nearly all the subjects learned more sequences at the first than at any other presentation. Of the 'good' memorisers only Wo. seems to have given her attention habitually at the first presentation to apprehending or 'taking stock' of the series-members rather than to connecting them. G. excelled the other subjects more in the amount learned upon the first presentation than in the speed with which an entirely correct reconstruction was achieved. But when series were hard for any subject—hard on account of material or on account of length—then more 'new' sequences were mastered at the second than at the first presentation. This fact may be illustrated with the series of 41 colors and 41 smells learned by G at

about the same time (in the spring of 1904) in the second year of the color and third year of the smell work. In the case of the smells 68.4 per cent of the sequences were reproduced at the first trial, and 95.2 per cent at the second. Thus roughly speaking we may say that 68.4 per cent of the smell-sequences were learned on the first presentation and 26.8 per cent at the second. In the case of the colors, 25.3 per cent of the color-sequences were reproduced at the first trial and 81.1 per cent at the second. Thus we may say, roughly, that 25.3 per cent of the sequences were learned on the first trial and 55-8 on the second. The colors were notoriously hard for G. to discriminate. In short, one may conclude that in the case of a long or otherwise hard series the presentation during which the subject does most of his memorising must be preceded by at least one presentation during which the subject is for the most part occupied with that apprehending which is the conscious condition of discriminating the series-members.[1]

c. A third difference between the three kinds of material is their relative attention-value or strikingness (*Eindringlichkeit*). The strikingness of a smell depends upon its intensity and upon its affective value apart from intensity. The intensity of certain scents has its correlate in the saturation of certain colors. Any one of the pure spectral colors from violet-red through yellow to blue-green 'catches the eye' of the subject, whether it contrasts in hue or brightness with its neighbors or not. So far as memorising is concerned photometric value cannot be considered as the direct analogue of smell-intensity, for the paler tints are not especially striking. Nevertheless, it seems to be the difference in brightness which makes the spectral colors

[1] In learning by the method of complete memorising series of syllables presented to the eye, Ebert and Meumann (*op. cit.*, pp. 43–45) distinguish five stages: (1) *Orientieren*; (2) *apperzierendes Lesen*; (3) *rhythmisierendes Lesen*; (4) *antizipierendes Lesen*; and (5) *probierendes, kontrollierendes Lesen.* In the stage of orientation, mistakes in reading occur; in the second stage reading is smooth and monotonous. In our own experiments, the stages corresponding to the second and third of these five stages were blended, but in the difficult series the stage of orientation was sharply marked off. On the relatively large amount ordinarily accomplished by the first presentation, see Ebbinghaus, *Grundzüge*, 2d edition, p. 652, with the references given on p. 651.

from red through yellow to blue-green so much more 'striking' than the spectral colors from blue to blue-violet. The pleasantness and unpleasantness possessed by certain smells, apart from their intensity, have correlates in the pleasingness and unpleasingness of certain colors, apart from their saturation. Of course the nonsense-syllables do not vary in strikingness in the same degree in which the smells and colors vary. Nevertheless, their variation is by no means to be overlooked. The strikingness of a syllable as a whole depends largely upon the strikingness of its component letters. Müller and Pilzecker conclude (from an analysis of the partially right cases which they obtained by the *Treffermethode*) that the following circumstances make a letter easier to remember; (1) its auditory or visual strikingness (*Eindringlichkeit*), (2) its rarity in ordinary speech, and (3) the difficulty of pronunciation. By those of their subjects who were of strongly auditory type, *eu* and *ö* among the vowels were best remembered. *Eu* is not very common and its sound is prolonged. *Ö* resembles it and was in the reading pronounced with especial pains. *Aa* was best remembered by subjects of weakly auditory type. Among consonants *sch* was best remembered by both classes of subjects. For G. the strikingness of a syllable depended much upon the vividness of its color. The other subjects made no comment upon the relative attention-value of the various syllables.

However, although the syllables differ considerably from one another in attention-value, yet they have very little intrinsic interest as compared with the colors and the smells. As a German victim has put it, nonsense-syllables are '*schrecklich sinnlos*.' In the matter of attention-value the concrete material has a certain offset to the ease with which the syllables are apprehended and discriminated. To most of the subjects the æsthetic value of the colors was much less important than the affective value of the smells. Many persons seem incapable of being appreciably pleased or displeased by a small square of colored paper. With G. the case was reversed. The affective value of odors, except in a few instances, had almost entirely worn off before these experiments had begun. On the other hand, although a color was seldom noted for its ugliness, yet the

prettiness of certain colors and color-combinations was a perennial source of satisfaction. Nevertheless, the affective value of the colors proved no great offset to the difficulty of distinguishing them from one another.

In considering the affective value of the concrete material, the writer has examined about 300 cases in which not more than two sequences were correctly reproduced in the reconstruction of smell- or color-series which involved each at least nine possible right cases. The object of the scrutiny was to determine why these particular sequences had 'impressed themselves' on the memory of the subject. In only about 11 per cent of the total number of cases could the singling out of these sequences be explained by the pleasantness or unpleasantness of one or both members, or by the pleasing or unpleasing combination of two members. In about 47 per cent of the total number of cases, the sequences in question stood at or near the beginning or at the end of the series. Most of the other cases among the smells are explicable by the great strength or familiarity of both odors; most of the other cases among the colors are explicable by similarity of hue.

From these negative results the writer concludes not that affective value is an unimportant factor in memorising, but that in the course of these experiments the affective value rapidly wore off the colors and smells.[1] Moreover, the results presented, in their very nature, must fail to do justice to the importance of such affective value as persisted. When a few sequences are especially easy to remember, more 'energy' is left over for the others—i. e., attention remains more stable—and the whole series may be so nearly memorised that in the objective results the mastery of no particular fragment stands out. Nevertheless, the greater attention-value of the smells and colors does not seem to have been a very important offset to the dis-

[1] The writer dissents utterly from the conclusions reached by Miss Kate Gordon in regard to affective value as a factor in memorising certain designs. See *Arch. für gesammte Psychologie*, iv, pp. 437–458. Miss H. D. Cook in criticising the argument in the *Psychological Review*, seems to have pointed out the real reason why the experiments in question had a negative outcome, namely, that it was the design as a whole which was pleasant or unpleasant, whereas the subjects were required to reproduce the details.

tinctness and the discreteness of the syllables. The order of advantage as regards attention value is 'colors or smells, smells or colors, syllables.'

d. The fourth difference between the three sorts of materials lies in the relative richness of the units in associations which are extrinsic to particular series. Associations with series-members which are extrinsic to the series itself may either help or hinder the process of memorising. (1) If the ideas associated with the different members have nothing to do with their neighbors or their places in other series, then they will act as 'aids to attention' or 'aids to linkage.' The association of violets with a particular person draws special attention to the perfume; the idea 'Gloucester' forms an associative link between the smells of whale-oil and tar. (2) Occasionally, the memory of the position of a series-member in another series may be an aid to attention. (3) As a rule, however, associations formed with the m mbers of a given series in earlier series, whether they produce actual memory-images or remain mere physiological tendencies to remember, will hamper the memorising of the new series through anticipatory inhibition, or will hamper its proper reconstruction through reciprocal inhibition, or will have both effects. If on a given day lemon is the tenth smell of a series and comes after amber, and on the next day is the thirteenth smell and comes after something else, then any one of several things may happen. On the one hand, the subject may be confused by the difference in position. Then, in the first attempts at reconstruction, he may not 'remember anything about' lemon, or he may choose to put it after civet or some other smell resembling amber, or he may put it in the tenth place regardless of its new neighbors. On the other hand, as was stated, the old associations may aid in memorising the new series. When the new series is presented the subject may rapidly and accurately compare the two positions and thus make out of the past history of the lemon-smell an aid to attention. Such comparisons are, however, never made except by good subjects under favorable circumstances. As a matter of fact, the same scent and color occurred very often indeed from series

to series, since not more than 129 scents and 136 colors were ever in use at any one time, and since fewer than thirty scents were rarely given, even to the most unpracticed subjects, at any one sitting. Thus, it became impossible to trace the history of a smell from series to series. Indeed if 'retroactive inhibition' had not kept 'wiping the slate' in a manner which will be noted, th legible recording of the new series would have been impossible.[1] In short, such vestiges of old series as remained over from day to day were, in general, only a source of confusion.

The nonsense-syllables were no poorer than the colors and smells in serviceable associations, and were much freer from troublesome associations. At first thought one is inclined to suppose that the colors and smells must come laden with extrinsic associations and to dwell on the meaningless character of the syllables. This view, however, is not just. All the common colors have been factors in so many different experiences that the associations cancel and the color becomes almost like a numeral or letter. (Cf. page 28.) Much has been said of the reminiscent power of smells, but the popular notion has sustained rebuttal rather than verification when tested by experiment.[2] The truth seems (to the writer) to be that

[1] The distinction between the three kinds of inhibition which the present writer calls *retroactive*, *anticipatory*, and *reciprocal* is taken from Müller and Pilzecker, *op. cit.*, pp. 138–140, 144–157, and 194–198, and from Ebbinghaus, *Grundzüge*, pp. 686 and 694–695. Anticipatory inhibition is called by Ebbinghaus *associative* and by Müller and Pilzecker *generative Hemmung*. Reciprocal inhibition is called by Ebbinghaus *reproductive* and by Müller and Pilzecker *effectuelle Hemmung*. Retractive inhibition is the breaking up of an old association by a new one, or set of associations by new ones, as, for example, when the learning of a new series of smells 'drives the old series out of one's head.' Anticipatory inhibition is the hampering or hindering of the formation of a new association by an old one, as when, for example, the memory *lemon—amber* makes the sequence *lemon—strawberry* 'hard to learn.' Reciprocal inhibition is the mutual interference of two associations both fully formed and both attaching to the same experience. (It is the Kilkenny-cat form of inhibition.) For example, the conflicting associations *lemon amber* and *lemon strawberry* may so 'block each other that the subject's 'head is a blank.' Or if the first association is the stronger, the image *amber* may appear after some delay and may or may not be followed after an interval by the image *strawberry*.

[2] See Heywood and Vortriede: *Some Experiments on the Associative Power of Smells*, Am. Jour. Psych., xvii, pp. 537–541, and Bolger and Titchener under same title, same Journal, xviii, pp. 326–327.

unaccustomed smells have reminiscent power, and that they tend to recall the same images every time they occur, whereas the commonplace smells of our daily life have no more reminiscent value than the blue of the sky or the click of a typewriter. They have so many associative connections that very few associated images appear in consciousness apart from the stereotyped images which are serviceable in practical life. For G. the reminiscent as well as the affective value of most of the smells had worn off before these experiments were begun. The subjects who were dull in apprehending the scents are not likely to have associated very definite images with them. On the other hand, G. is convinced from self-observation and from the remarks of the other subjects that the syllables, when clearly apprehended, were especially fertile in verbal associates. Furthermore, G. urges that in their freedom from troublesome associations, the syllables had an immense advantage over the smells and colors. As the smell and color experiments proceeded month after month, G. felt that anticipatory inhibition tended strongly to counteract the effect of practice. The subject often compared her 'mind,'—i. e., the background upon which she projected her color-images (see page 106)—to a school black-board which is dusty and blurred at the end of a week but is washed clean and black for Monday.

With G. retroactive inhibition was obvious. Each series was remembered fairly well until the next was given. That is to say, the subject could name hours afterwards the members of the last series given, and the associations involved would remain almost undisturbed for weeks.[1] But as soon as a new series was given, the eraser (the subject actually visualised a blackboard eraser in this connection) was drawn over the old series. A 'smudge' might remain to make the new series illegible but the old one could no longer be read off.

One may sum up the case in regard to extrinsic associations by saying that the order of advantage is the following: 'Syllables, then smells and colors.'

It seems proper to introduce here certain data which bear

[1] *In Bereitschaft*—ready to function.

both upon the degree of practice to which G. had attained and upon the effect of anticipatory and reciprocal inhibition.

In each of the nine periods belonging to the first group of experiments, the results were massed, not only according to series-length, but also according to certain of the general conditions under which they were obtained. In the first place, the results obtained at each of several grades of 'physical condition' were massed apart. The physical condition was graded *A*, if the subject was free both from general fatigue and from more specific discomfort. It was graded *B* if she was 'tired' but was free from discomfort not ordinarily covered by that elastic term. It was graded *C* or *D* if she had a headache or any other positive ailment. In the second place, the results obtained in the hours following 9:00 a.m., 4:30 p.m. and 9:00 p.m. were massed apart. Lastly, in the four periods of the first year, the results obtained on Monday and Tuesday, those obtained on Wednesday and Thursday, and those obtained on Friday and Saturday were massed in separate sets. The following conclusions may be drawn from the figures thus reached:

1. The facility of this subject in memorising depends to a surprisingly slight extent upon her physical condition. In the earlier part of the work, she memorised rather more readily at *A*, but in the last two periods of the second year, she learned somewhat more readily at *B*. The very first and last periods of the nine offer fair specimens of the differences. In the first period, G. learned 81 series at the condition marked *A*, 73 series at *B*, and 34 series at *C*. (Her condition at the end of any hard day's work was marked *B*; the letter indicates no pathological state.) The average series-lengths were respectively 10.1, 9.9, and 9.9. The average numbers of repetitions necessary to correct reconstruction were 1.7, 1.8, and 1.9. The percentages of right sequences obtained on the first trial were 71.6, 67.7, and 69.3. In the last period of all, G. learned 11 series at *A*, 25 series at *B*, and 4 series at *C*. The average lengths were respectively 33.2, 33.8, and 30.8. The numbers of repetitions necessary to correct reconstruction were 1.9, 1.8, and 1.8. The numbers necessary to a perfect reconstruction were 2.0, 2.3. and 2.0. The percentages of right sequences obtained at the first trial were 71.5, 80.5, and 63.9.

2. The subject memorised more readily in the morning than in the afternoon or evening, except in the last two periods of the second year. In the very last period she learned distinctly better in the evening. The experiments made in the daytime were made in the laboratory; those made in the evening were made at home. Evidently, the freedom from interruption secured at home tended to counterbalance the fatigue at the end of the day. The subject's physical condition was ordinarily graded *B* in the evening. Thus the fact that at this time she memorised better in the evening explains the fact that she appeared to memorise better when tired.

3. The subject learned more easily on Monday and Tuesday than on the later days of the week. In the last period of the first year—the last period in which the results were massed according to the days of the week on which they were obtained—the figures are as follows: On Monday and Tuesday, 62 series were learned; on Wednesday and Thursday, 93; on Friday and Saturday, 85. The average lengths were respectively 14.6, 14.4 and 14.5. The average numbers of repetitions necessary to a correct reconstruction were 1.4, 1.5, and 1.5. The numbers necessary to a perfect reconstruction were 1.7, 1.9, and 1.7. The percentages of sequences obtained at the first trial were 89.2, 82.3, and 82.6. The better results obtained early in the week cannot be explained wholly by the fact that the subject was in better physical trim, for in this period she learned about as well at *B* as at *A*, although the later work of the day was done in the afternoon amid the interruptions of the laboratory. The results as a whole give a slight but distinct indication that a short intermission in the work was in itself an advantage and that G.'s assertion in regard to the effect of the Sunday rest was not altogether fanciful.[1]

The results of no other subject have been carefully examined to gauge the effect of fatigue. A cursory examination, however, tends to confirm the observation of ordinary life that with most

[1] Cf. Müller and Schuman, *op. cit.* p. 328. As stated on p. 74 experiments were sometimes made on Sunday in the second year, of this group in order to test the effect of cutting out the day's rest. It proved impossible, however, to make the Sunday work regular.

persons learning progresses much better when the learner is well and fresh. The case of G. seems to have been unusual as regards the small difference made by fatigue and illness, but this small difference is probably 'a mere matter of practice.' According to several investigators, the overcoming of one's disinclination is no small part of practice in memorising, and it is certain that many of us allow the weakness of the flesh to impede us most in the tasks which are most odious to us. The series interested G.; therefore, they held her attention even toward the end of a long day's work.

e. The fifth difference between the three kinds of material which must here be discussed is the difference in heterogeneity. By heterogeneity the writer means any kind of variety, even the variety created by the very familiar among the unfamiliar. Very intense, pungent, unpleasant, or familiar odors, glaring colors, sharply contrasting or æsthetically pleasing pairs of colors, black or white set among the colors, word-like or liquid syllables or rhyming pairs of syllables,—in short, any unusual units or combinations of units,—are apt to form 'pillars' to which in the process of memorising other units are attached. The greater the number of such pillars and the more even their distribution throughout the series, the easier the series is to learn, at least within limits which are not likely to be transgressed in the case of series made up by chance. To be sure, the strikingness of certain links in a series is not an unmixed blessing to the subject. The uncouthness of certain syllables such as *thoth* may distract attention from the all-important matter of series-order. So also the 'shock' of a very unpleasant smell may distract attention from its position—especially if emotional disturbance supervenes. On the whole, however, the variegated series is learned with appreciably less effort.

In the matter of variety, the smell-series have the advantage over the colors and obviously both kinds of concrete material have a great advantage over the syllables. In the experience of G. variety is the chief advantage which the smell and color series have. This opinion of G. was submitted to a rough experimental test: If variety makes a series easier to memorise then it

might be argued that a series containing both colors and smells would be easier to memorise than a series formed of colors only or of smells only. We tested this supposition experimentally. To G. smells series made up of alternate colors and smells were given in turn with series made up wholly of smells and wholly of colors. The nature of the scents was concealed from the subject's eye in the manner described on page 16. When the mixed series contained an uneven number of members a color stood at the beginning and at the end. These experiments were made in the spring of 1906 and overlap the control-experiments described on pages 108–109.

The results with G. were as follows:

Series.	*Procedure.*	*ML.*	*N.*	*Nr.*	*Wr.*	*MV.*	*Np.*	*Wp.*	*MV.*
Smells....	With blindfolding	25.5	10	8	1.6	0.8	8	2.0	1.0
Smells....	Without blindfolding	25.5	10	10	1.5	0.5	10	1.9	0.5
Colors....	Normal	25.5	20	18	1.9	0.7	18	2.3	1.2
Mixed....		25.5	20	20	1.5	0.6	20	1.9	0.6

The series-lengths used were 12, 24, and 41. From the results it would seem that the mixed series were easier for G. to learn than the colors, but were neither easier nor harder to learn than the unmixed smell-series when the blindfolding handicap was removed. Their mixed character seemed to atone for the presence of the colors. The subject had had no previous practice in learning mixed series. The members were learned in single series, that is, the subject did not connect color to color or smell to smell, skipping the disparate link.

The following results were obtained from 19 beginners (not the beginners who served in the experiments of Groups II, III, and IV):

Series.	*L.*	*N.*	*RS%* $W = 1.$	*RP%* $W = 1.$	*L.*	*N.*	*RS%* $W = 1.$	*RP%* $W = 1.$
Mixed.....	17	304	38.8	54.9	25	303	22.0	36.8
Colors.....	17	19	41.4	46.7	25	19	25.7	28.5
Smells.....	17	16	27.3	36.7	25	15	17.5	21.1

Series as long as 17 and 25 were used in order that the numbers of repetitions necessary for reconstruction might not be so small for both lengths as to approximate to one another. As a matter of fact, however, so few of the series were ever reconstructed correctly or perfectly that the values of *Wr* and *Wp* are not worth giving. The unmixed series of smells and colors were given at the end of the experiments with the mixed series.[1] The results, just given, when eked out by an examination of the individual records, show that the variety of the mixed series was an advantage in memorising positions but that the presence of the smells was a disadvantage in memorising sequences. The mixed series were easier to learn than the series composed entirely of smells; the difficulty of memorising the sequences in the mixed series evidently depended not upon the fact of mixture but upon the difficulty of learning the smells. The subjects dealt with the mixed series in three different ways. Five subjects out of the nineteen were like G. in uniting the two kinds of members into a single series. Six subjects, on the other hand, learned the smells and colors in two separate series, connecting color with color and smell with smell. Eight subjects followed a middle course, learning the color-sequences or positions as a scaffolding and connecting each smell to the color preceding or following. It cannot be said that one of these methods proved more successful than another. The best memoriser in this group of beginners followed the second method which seems the most awkward. Position-notions did not seem to be relatively important in learning the mixed series; seventeen of the nineteen subjects claim to have noted both sequences and positions.

Our results, as far as they go, are evidently somewhat at variance with those of Münsterberg and Bigham.[2] It would be worth while to investigate the point at issue with more

[1] Two series-lengths were used for purposes of illustration and instruction. It is obvious that the experiments were badly planned as regards their bearing upon the point here under discussion.

[2] Münsterberg and Bigham, *op. cit.*, p. 37.

extended experiments. The data in hand are too scanty to make further discussion profitable.

Before closing the discussion of variety among series-members it should be noted incidentally that the rhymes, alliterations and assonances which occur in the hit-or-miss series of nonsense-syllables have their parallel in the case of the series of colors and smells. The presence of smells of the same subgroup—the presence, for example, of several spices or mints—makes the series easier rather than harder, provided that the smells are easily discriminated. The subject is aided by rapid comparisons of this sort: 'cloves in such a place—cinnamon in such another; peppermint here—wintergreen there.' It is only a certain great degree of similarity between the odors which creates difficulty. So, also, a color-series is made easier by the presence of similar yet easily discriminable colors such as the spectral green and blue-green. All three sorts of series are extremely liable to the favorable accident of similarity between some few of the links.

In the matter of variety, the order of advantage is the following; 'smells, colors, syllables.'

f. A sixth point of difference between the kinds of materials lies in the fact that the difficulty of a smell-series depends upon the assortment and order of the qualities in a fashion which has no analogue in the case of the syllables and only a very rough one in the case of the colors. In the case of the smells one has to reckon with the phenomena of exhaustion. When smells which are very similar come next to one another in a series, then (1) the qualitative difference between them may be obscured, (2) the quality of the scent or scents which come later may be perverted and (3) the intensity of these later scents may be considerably diminished. An illustration of this last and most important alteration is that vanilla is almost odorless when smelled after a strong flower perfume. An instance of perversion from exhaustion is the shoe-polish odor taken on by the almond-like nitrobenzol. Qualitative alterations with the

small degree of exhaustion which here comes in question,[1] were very rarely noted by the principal subject except when several artificial perfumes occurred in succession. Theoretically, the degree to which exhaustion is likely to prove troublesome depends not only upon the juxtaposition of similar smells but also upon the quality of the odors in the series at large. Some smells, notably those of the fragrant group, are more exhausting than others. In the experience of the principal subject, however, the differences in the exhausting effect of different series were, apart from the length of the series, of no importance whatsoever. Nor did this subject actually observe that the intensity of an odor depended upon the number of other smells which had preceded it in the series. As a matter of fact, she noted the exhaustion-phenomena only (1) when a strong smell was followed by a weaker one of somewhat similar quality, (2) when several artificial perfumes came together, and (3) after general fatigue had begun to set in.

In the case of the color-series one finds a very rough parallel to the effect of exhaustion in that of adaptation.[2] This is important only as it occasionally makes itself felt in successive contrast-effects. The most extreme instance of this effect occurs when a neutral gray coming after a saturated color appears tinged with the complementary hue. The really neu-

[1] A distinction is drawn between this slight and local exhaustion and the kind of fatigue felt at the end of an experimental sitting. In this second sort of fatigue, both brain and sense-organ are involved. Exhaustion, in the technical sense and in the opinion of the present writer, is a fatigue phenomenon, but it is scarcely fatigue in the ordinary laboratory acceptation.

[2] In the opinion of the writer, the smell phenomenon which is ordinarily called exhaustion cannot be considered as analogous to visual adaptation because it has no contrast effects. There are no negative after-images of smells and there are no clear instances of successive contrast. Occasionally one smell in a series will catch the attention because it is preceded by others which are different in quality, but this fact does not imply any sense-organ contrast. Moreover, there is an actual blurring of difference between two similar smells occurring in close succession, whereas there is some contrast even between two very similar colors. (Orange, for example, takes on a more yellowish cast when seen after scarlet.) It is palpably true that smells do not 'throw each other off as far as possible' in the fashion of 'color-antagonism.' The only possible color parallel to the mutually levelling effect of two odors when smelled turn about is the extremely distant and doubtful one of the washing of colors over one another after simultaneous light induction has had time to set in.

tral gray may then be confused with a really colored gray in the same series. Since in each attempt at reconstruction the colors are presented to the subject in random order and not in the order of presentation, it is evident that perplexities must sometimes have arisen from an apparent alteration in the smells and colors themselves. To take again a most extreme instance, the same neutral gray which looked greenish in the series because it followed scarlet might look reddish when the links were presented for rearrangement because it followed blue-green. In the experience of G. such perversions were very frequent indeed. On the whole, however, the order of advantage in freedom from such alterations is 'syllables, colors, smells.'

g. The last point to be discussed in this chapter is the gross difference between visible and invisible material. Under this heading two questions arise: 1. The most important question is in regard to the degree of advantage which the colors and syllables received from being spread out before the subject's eyes in the process of reconstruction. To determine the degree of advantage a small number of control experiments have just been made (in the fall of 1908). In one of the two sets of experiments compared, series of colors were given according to the standard method, with the single unimportant variation of not handling the first link to the subject as a 'starter.' In the other set of experiments, the color-squares were covered one after another with squares of white (or buff) paper as soon as they were placed by the subject in the process of reconstruction. This covering of the colors makes the conditions comparable to the conditions in the smell-experiments in which the subject was not blindfolded; the subject has to remember the nature of the links already placed, but is not compelled to 'feel his way' in the act of placing. The series were all of the length 20. No importance was attached to certainty of correctness, but the placing-rules were the same as in the older experiments. The two procedures were used according to a compensating program. The subjects A. and Wil. were advanced students. The results were as follows:

Subject.	*Method.*	*N.*	*Wr.*	*MV.*	*Wp.*	*MV.*	*RS%* $W = 1$.
G.....	Normal	20	2.2	0.3	2.5	0.6	47.6
	Covered series	20	2.8	0.8	3.4	1.0	41.6
A.....	Normal	10	2.7	0.6	3.2	0.7	34.2
	Covered series	10	3.3	0.8	3.6	0.7	24.7
Wil.....	Normal	7	3.6	1.1	4.1	1.0	15.8
	Covered series	8	4.5	0.8	5.0	1.0	18.4

The figures demonstrated exactly that which one would conjecture without them, namely, that it is harder to reconstruct the color-series when one's work remains in part invisible. The difference is not overwhelming. According to the introspection of the subjects the difficulty in correctly rearranging the covered series lay mainly in the fact that very similar colors could not, as in the normal method, be compared in the process of reconstruction. (In the work with the covered series no two colors were ever seen simultaneously.) The subjects had no appreciable trouble in remembering the approximate nature of the links placed and covered. The length of the series was not great enough to make this task very arduous, but G. was surprised to find it as slight as it proved. No subject noted that the actual appearance of the links acted more definitely than the images of the covered links in the way of reproductive reinforcement. (See page 33.) On the whole, one may infer that the covering of the color-series would not have made them as difficult as the smells for the majority of the subjects but would have made them for G. even more difficult than they relatively were. It is practically certain that covering the syllables would not have introduced so much difficulty as covering the colors introduced, for the difficulty of discriminating the syllables from one another is negligible.

2. A less important question in regard to the difference between the visible and invisible material is in regard to the degree in which blindfolding handicapped the subjects in the normal procedure with the smell-material. The fact has already been emphasised that the subjects could not be allowed

in any case to tell the bottles apart by their appearance (page 38), but the expedient described on page 6—the use of the blue cotton—concealed the color of liquid scents and yet removed the peculiar difficulties of blindfold work.[1] These difficulties consist mainly in the facts that the groping hand-movements require considerable attention and that the subject is liable to disturbing accidents—likely to knock bottles off the table, for example. Control experiments to test the magnitude of the blindfolding-handicap were made only with G., were few in number, and are the less valuable because they were made after the subject had learned by long practice to surmount this handicap. The experiments in question form two of the sets described on pages 108-109. The results are given on page 142. The figures show that at this time the subject was placed only at the slightest possible disadvantage by the blindfolding. It seemed to her that she memorised better with the eye-bandage than without it, but this impression was no doubt due to disappointment at the smallness of the advantage in seeing the bottles. But however successfully G. finally surmounted the handicap of the eye-bandage and however easy it proved for her to remember the nature of the colors placed even when they were immediately covered from view, nevertheless, the fact remains that she was most conscious of strain in memorising the smell-series and that she attributed this fact to the double effort to remember both the order of the scents and the contents of the bottles placed. Since covering the color-series made them more difficult to reconstruct and since making the scent bottles visible made the smell-series easier to rearrange even for a subject long-inured to blindfold-work, we may certainly infer that the *syllables and colors have an advantage over the smell-series in the mere fact of being visible.*

The writer, as the subject G., draws the following conclusion from the various data presented in this chapter:

1. *In the case of long series, the order of the syllables was dis-*

[1] The only disadvantage in the procedure is that it cuts out the use of a number of very desirable solid scents.

tinctly easier to learn than the order of the smells and colors, certainly for herself and probably for the other subjects.

2. *When series are so short as to present few difficulties in discrimination, and so few that anticipatory and reciprocal inhibition do not come into play, then the concrete material has the advantage because it is more varied and more interesting.*

3. *The approximation of the numbers of necessary repetitions with the three sorts of series was due to the fact that memorising the order of all three sorts of units by the reconstruction method was so easy as to leave little margin for variation.*

4. *Neither the numerical results nor the introspective observations reveal any essential difference in the mental processes concerned in memorising the three kinds of series.*

CHAPTER VI.

AN EXPERIMENTAL STUDY OF THE RECONSTRUCTION METHOD AS USED IN THESE EXPERIMENTS

This chapter contains an account of certain groups of experiments which were made to test the various explanations proposed for the results reached on pages 87–89. It has been demonstrated that practice enables the subject to memorise by our reconstruction method the order of very long series of smells or of colors or of nonsense-syllables with a very small number of repetitions, and that this number does not vary greatly with the length of the series. Why, then, is it so easy to memorise serial order by this method and why does length make so little difference? The introspection of the subjects bears out to some extent the truth of all the solutions proposed in Chapter I for the first problem. The purpose of the experiments reported in this chapter was to put these five explanations to a more rigid test than the introspective.

It seems impossible to describe these experiments briefly in either a strictly logical or a strictly chronological order. In the first section of this chapter the different groups are treated in the order which best ensures conciseness. In the second section, an attempt is made to combine and explain the various results.

A. Account of the Experiments.

I. The first group of experiments with which one has here to deal, Group VI, bears upon the *explanation by long intervals* (see page 10). The experiments were made with smells by the normal reconstruction method except that the subjects were required in (about) half the experiments to do simple sums in addition while the units were in course of presentation. As each bottle was given a number was named which the subject was required to add to the sum of all the preceding num-

bers. The experimenter had ascertained the sum of the numbers beforehand, and recorded not merely the order in which the subject arranged the bottles but also whether the addition was right or wrong. The presentation of a series was repeated until the reconstruction was perfect and a correct 'answer' to the sum given in the corresponding presentation had been obtained. The subjects might add aloud but might not jot down the numbers. The experiments were originally designed as attention- and distraction-experiments. Hence, the numbers were given when the bottles were presented and not in the interval. However, as the subjects avowedly sandwiched the adding and the smelling, the arithmetic must have had the effect either of abbreviating the exposure-time, as far as attention was concerned, or else of filling, at least partially, the interval between exposures. The experimenters were charged not to allow any appreciable difference in the rate of presentation in the standard and in the distraction-series. Curiously enough, the additions were nearly always right, whether the series-order was learned or not. Cases in which the reconstruction was correct and the addition wrong form only about 6 per cent of the total number of reconstructions. The numbers to be added were in most sets of experiments under ten, but in a few sets they were two-place numbers between 10 and 20. One of the subjects remarked that it 'seemed a disgrace not to be able to add simple numbers.' Since the subjects took the greater pains with the adding, it seems probable that they did the adding first, during the actual presence of the odor and did the deliberate linking of the odor afterwards, in part during the relatively empty interval. The introspective records of these experiments are fragmentary.

The experiments extended through most of the year 1902–1903. The four subjects were all students in a second-year course and all worked as experimenters as well as subjects. One served six times a week as subject; the others three times.

The results of D.[1] will be given as showing the maximum effect of distraction:

[1] This was D.'s first year of smell-work. Cf. p. 72.

Series.	*Period.*	*L.*	*N.*	*RS%.*	*Nr.*	*Wr.*	*Np.*	*Wp.*
Standard.....	1	9	**17**	93.4	17	1.2	17	1.4
Single digits.....	1	9	**19**	79.6	18	1.4	17	1.8
Standard.....	1	12	**21**	77.5	20	1.7	18	2.3
Single digits.....	1	12	**20**	46.8	19	2.2	19	2.5
Standard.....	2	9	**14**	90.2	13	1.2	13	1.5
Two-place numbers.....	2	9	**14**	68.8	14	1.8	13	2.1
Standard.....	2	12	**17**	93.6	17	1.2	16	1.3
Two place numbers.....	2	12	**14**	66.4	14	1.9	14	2.4
Standard.....	3	18	**13**	88.7	13	1.5	13	1.8
Single digits.....	3	18	**14**	68.9	14	2.2	13	2.8
Standard	3	24	**12**	69.9	12	1.8	12	2.2
Single digits.....	3	24	**14**	62.1	14	2.1	13	2.5

Of course, the expressions 'single digits' and 'two-place numbers' refer to the numbers added in the distraction-series. Within each period, the different lengths and the standard and distraction-series were used in cyclic order.

The figures show that either the curtailing of the subject's time for memorising, or the shifting of attention between the two tasks imposed, or both, had an appreciable effect in raising the average number of repetitions necessary to learn the series and in lowering the number of sequences learned at the first trial, but that the values of *Wr* and *Wp* remain very small and are very little affected by difference in series-length. With none of the other subjects did distraction have nearly so much effect as with D. With two of them when the numbers to be added were single and the series short, the values of *Wr* and *Wp* were in a few cases actually smaller in the distraction than in the normal series.

In brief, one may conclude from these experiments that the memorising of serial order is so easy by the method under examination that the subject can bear a considerable abridgment of the leisure given for memorising, provided at least that the objective rate at which the units are given is not increased. Sometimes, evidently, the task, when easiest, is not quite hard enough without

distraction to raise attention to its highest level and to keep it taut. It may be noted that Coover and Angell consider the kind of attention most favorable for memorising to be a 'uniform state which is less than the maximum.'

II. The second group of experiments to be considered here, Group VII, bears upon *the explanation by presence of the links.* (See page 7.) The experiments were made with English normal series of nonsense-syllables of the length 12. Two methods were used *pari passu*, namely, our normal reconstruction method with one variation, and a modification of the method of retained numbers. The details of this second method were as follows: The series was presented in exactly the same fashion as when the normal reconstruction method was used. The same cards and tables were used as in the experiments of Group IV. When a series had been once presented, the subject was required to write down as many syllables as she remembered as nearly as possible in the right order. Her time was not limited. When she was done, the experimenter examined the slip of paper. If there were any mistakes whatsoever,—misspellings, omissions, interpolations, or transpositions,—the experimenter laid the first slip aside, presented the series again, and called for a new reproduction. This process was repeated until the reproduction was faultless. In these experiments, since the series were presented to the eye, no substitutions such as *c* for *k* or *se* for *ze* were allowed. The subject was told before the first presentation of a series whether she would be asked to reproduce or to reconstruct it. She was required to pronounce each syllable as it was presented and was corrected if she pronounced it improperly. The slips of paper were uniform and the subject was required to write the syllables in a column.

Two kinds of right cases were counted, namely, the syllables retained, whether they were reproduced in the right order or not, and the right sequences. In reckoning the number of members retained, 'half-right members' were taken into account. A syllable was reckoned as 'half' right when two of the three elements were exactly as given or when the initial and final elements were transposed. In the table given below two half-right

members are counted as one wholly right member. Sequences of half-right members or of a half-right and a wholly right member or the reverse were not counted. Therefore, one sequence implies two wholly right members.

In the reconstruction experiments the first syllable-card was not handed to the subject but was shuffled with the rest. Therefore, in each series of 12 members, 12 right positions but only 11 right sequences were possible. This was the single variation from the normal method.

The experiments were made in the spring of 1908. The subjects were 6 beginners, who are indicated in the table by numbers. The experimenters were 6 other beginners who worked under very close oversight. The same series were used with all the subjects in each of the two sets of experiments. The series were written on the cards and dealt out by the director. The program, not only from day to day but for each sitting, was so arranged as to make the effect of practice bear equally upon the two kinds of experiments. At first, three series were learned at a sitting; then four.

The results are contained in Table X.

Although these experiments were made upon beginners and were not very numerous, yet in the opinion of the writer the results throw the explanation by presence of the links once for all into a position of minor importance. (To these results should, of course, be added the results of the somewhat similar experiments made upon G. and reported on page 118.) *It is somewhat harder to reproduce a series perfectly from memory than to reconstruct it, but it is not very much harder.* In the case of only 2 subjects out of the 6 is *Wp* even $1\frac{1}{3}$ times as great in the reproduction as in the reconstruction experiments.

The relatively large number of members retained in isolation or in the wrong order appears to the writer to be not without significance. Inspection of the right-case columns seems so show that, in the reproduction series, the subjects were much more likely to retain syllables without any notion of their order than they were in the reconstruction series to remember the mere positions of syllables without any notion of their neighbors.

TABLE X.

To Show the Relative Difficulty of Memorising in the Case of Nonsense-Syllables, Series-Members and Series-Order.

Subject.	*Method.*	*N*.*	*Wr.*	*MV.*	*Wp.*	*MV.*	*RS% W = 1.*	Retained members or right positions % *W* = 1.
1	Reproduction	15	.....	.....	4.9	1.0	11.5	44.7
	Reconstruction	16	3.3	0.8	3.7	0.9	33.5	34.9
2	Reproduction	20	.....	.....	4.4	0.7	19.8	45.4
	Reconstruction	20	3.2	0.7	3.2	0.7	42.3	51.3
3	Reproduction	20	.....	.....	3.1	0.9	35.9	67.5
	Reconstruction	20	2.1	0.5	2.7	0.7	61.4	66.3
4	Reproduction	20	.....	.....	2.3	0.5	45.0	72.1
	Reconstruction	20	1.8	0.5	2.0	0.3	69.1	79.6
5	Reproduction	20	.....	.....	3.4	0.6	27.7	58.8
	Reconstruction	20	2.5	0.7	2.8	0.6	52.3	60.0
6	Reproduction	20	.....	.....	3.0	0.5	.....	63.3
	Reconstruction	20	2.2	0.9	2.5	0.9	72.2	75.0

* The values of Nr and Np were in every case the same as those of the corresponding N.

Mastery of the units in a series seems not infrequently to antedate mastery of their order. To be sure, among the wrong cases, omissions greatly outnumber transpositions. The fact seems to be that when syllables are learned at all, they are generally, but by no means always, learned in order.

The observations of the subjects throw some light upon the difference between the two sorts of memorising. Subject 5 reported that reconstruction was easier than reproduction because she 'did not have to learn the whole word but only certain letters of it.' Although this remark shows that less was learned in the reconstruction than in the reproduction experiments, yet it implies exactly that which the subject G. had asserted of herself, namely, that *the subject learned the units* (*or parts of them*) *as a means of learning the order.*

Subjects 5 and 6 spoke of a special set of extrinsic associations which connected the syllables of the reconstruction series with their numbers, and which may, in some cases, have made the *exact* recall of a syllable unnecessary. An instance would be the connecting of a syllable which had the initial *d*, the fourth letter of the alphabet, with the number 4.

In these reproduction series, all the subjects except Nos. 2 and 5 wrote down the last few syllables first and then 'went back' to the beginning. Subject 3 says expressly that while writing the last five or six syllables, she 'forgot the first ones or else the order.' The writer knows from experience (which will be stated later) that it is inadvisable to seize last impressions first —as one often does greedily, with the feeling that 'a bird in the hand is worth two in the bush.'

Subjects 2, 3 and 5 reported that they visualised the syllables better in the reconstruction experiments, and Subjects 2 and 3 explain the relative ease of reconstruction by this fact. The sharper visual imagery might have been due to the fact that in the process of reconstruction they saw the syllables again in the same hand-writing in which they were presented, or to the fact that they were more impressed by visual spatial relations when they arranged the cards on the table than when they wrote them on a slip of paper, or to the fact that in 'learning by heart' many persons rely by habit upon auditory and tactile imagery. In any case, the better visual imagery seems to have been considered by the subjects as a boon.[1]

All the subjects used auxiliary associations very freely. Many of those reported were of the 'story-type.' such as the connecting of *dave—gore—hoim* by '*Dave* came *home* with *bleeding* hands.'

After the first day, the effect of practice was not very marked and was, in the case of Subject 3, cut across by loss of interest. The first day's work of each subject was thrown out. Subject

[1] Subject 5 said that in the reproduction experiments her imagery was only auditory, whereas in the reconstruction experiments it was *both visual and auditory*—as if the advantage lay in the complexity of the imagery. Subject 2 said simply that 'learning was more oral in the reproduction series and more visual in the reconstruction series.'

1 (the poorest memoriser) said that practice consisted in 'learning to pay attention to the syllables' and finding that 'artificial connections were necessary' (*sic*). Subjects 2 and 6 spoke (spontaneously) of learning *not* to attend to all the syllables equally at each presentation ('economical distribution of attention'). Subject 2 also spoke of 'learning' to make artificial connections. Subject 3 said that practice consisted merely in 'getting used to the material and method.'

III. The third group of experiments to be considered, Group VIII, bears upon *the explanation by spatial localization.* (See page 9.) The design was to try the effect of eliminating such assistance as might be given to the subject by *reconstructing* the series in terms of spatial relations. Smells were used with one subject; nonsense-syllables with another. In one of the two sets of experiments to be compared, the normal reconstruction method was used. In the other set, the series was presented as usual, and the units were as usual handed to the subject in random order. Then, however, instead of actually arranging the units, the subject was required to state the numerical position of each in the series. The presentation and recitation of numbers was repeated until the latter was made without any mistakes—even mistakes at once corrected.

Subjects and experimenters were alike beginners. The supervision was close. The series of syllables were English normal series of the length 18. The smell work was done with the 'blue scents' (see page 16) and without the eye-bandage. The series were of the length 12. The two kinds of experiments to be compared were made in each case according to a cyclic and compensating program. Much of the smell-work had to be thrown out, so that the results are very scanty. The first day's work with the syllables was also thrown out. The results are given in Table XI.

The difference in the results for the two kinds of material is very easy to explain. Subject 1 (who memorises with rather extraordinary facility) says that memorising syllables by the reconstruction method was easier because she 'saw the series spread out' before her and this spreading out 'helped in mak-

ing artificial connections and in finding mistakes.' On the other hand, Subject 2 says that memorising smells by the 'number-method' was easier because 'one mistake in regard to a number did not involve a lot of others as one mistake in placing did.' It is evident that the difference in the situation lay in the fact that Subject 1 could *see* the series-cards which she had placed, whereas Subject 2 had to *remember* the contents of her bottles. Neither subject reports any help from spatial associations. Subject 1 is distinctly of the 'ingenius type.' Examples of her auxiliary associates are: *Rig—13—unlucky—upset in a rig; hive—13—angry swarm of bees*; *nab—13—having something*

TABLE XI

To Show the Relative Difficulty of Actually Reconstructing a Series from Memory and of Reciting the Numbers of the Units

Subject.	*Material.*	*Method.*	*N.*	*Nr.*	*Wr.*	*MV.*	*Np.*	*Wp.*	*MV.*	Right positions or numbers % *W* = 1,
1	Syllables	"Numbers"	16	16	2.3	0.5	16	2.3	0.5	70.5
	L. 18	Reconstruction	16	16	2.0	0.1	16	2.1	0.2	64.2
2	Smells	"Nos."	7	7	2.3	0.8	7	2.3	0.8	63.1
	L. 12	Rec.	8	8	3.0	0.8	7	3.0	0.9	53.1

*The subjects of these experiments were not the same as those of the last group. With one exception, no beginner served in two groups of experiments.

stolen. She complained that practice was counteracted by the 'multitude of associations forced upon' her 'from foregoing series' (inhibition).

Even if the series had been more numerous *the results of this group of experiments would be inconclusive as regards the special point at issue*. The statement of Subject 1, however, illustrates the fact that when a series is spread out before the subject's eyes, reproductive reinforcement is one of the advantages of the reconstruction method. (See page 33.) It is, however, impossible that this advantage is the all-important one for which we are looking. It is impossible because the smell-series at large do not share in it, and yet are very easily learned.

IV. The experiments of Group IX had the double purpose of testing the explanations (1) *by spatial localisation* and (2) *by multiplied tests of mastery.* (See page 9.) They were made by the writer in Göttingen in the spring of 1907 (*not* in Professor Müller's laboratory but privately). The material consisted of German normal series of nonsense-syllables written upon cards of 2 × 2½ inches and of small playing cards of 1½ × 2¼ inches. The subjects Ki. and Ho., were German women twenty-four and twenty-one years of age. Ki. had passed through the 'Mittelschule;' Ho. only through the 'Vorschule.' Ho. reads German fluently and writes an excellent script, but is slow in learning English words and in apprehending anything new and uninteresting. Laboratory experiments by the method of right associates had failed with her utterly.

So many different methods were used tentatively in these experiments and so few series were given by each method that space cannot be taken for a complete account. The experiments fall into four small subgroups. In regard to the first three subgroups the following statements must suffice:

a. In about half the series, the syllable-cards or playing cards were laid in rows of six or eight upon a table covered with black and were exposed simultaneously by lifting a long piece of cardboard. The subject was required to read the syllables or to name the cards aloud from left to right as from the page of a book. In the other half of the series the cards were presented successively according to our normal reconstruction method. This difference was introduced to try the effect of increasing the opportunity for forming spatial associations. In the first case the subjects were instructed to arrange the series 'just as it was before,' and in the second also they were required to rearrange it in horizontal rows of six or eight. No distinction was drawn between a correct and a perfect reconstruction. The cards when shuffled were handed over to the subject in a pack—not one by one.

Ki., who worked only with syllable-cards, learned slightly better when the cards were exposed simultaneously. Nevertheless, she preferred the other method, saying that when the cards were exposed simultaneously she 'saw too much at once.

Ho. learned decidedly better when the cards were exposed successively except only in the very last of the experiments under discussion. An example of what the writer means by learning decidedly better is this: *Wr* for one set of 8 series of the length 12 with simultaneous exposure is 4.6 and for the corresponding set with successive exposure of members is 3.3. In the last experiments, those in which Ho. did better with simultaneous exposure, the material consisted of playing cards.

The results are altogether inconclusive as regards the advantage of fostering spatial relations. The writer believes that the chief difference between the two subjects lay in the fact that Ho. 'gabbled' through the series, when the cards were exposed simultaneously, whereas Ki. read slowly and deliberately. The rapid rate was quite enough to counterbalance any advantage (as regards the *number of repetitions* necessary) which Ho. might have derived from spatial associations. (The writer had already failed in the laboratory to teach Ho. to read with the metronome.) That Ho. in the last experiments learned better with simultaneous exposure is doubtless explained by the combined facts that she had learned to read attentively and that the playing cards were represented, as the writer had hoped, by lively images in especially definite spatial relations.

b. In half the series of the first subgroup the subjects were required to rearrange the series after each presentation as in our normal reconstruction method. After the learning of each series was mastered in this fashion, another series was given with a number of preliminary presentations which was double the number required for learning the last series by the normal method. If, for example, the subject reconstructed Series A on the third trial, then Series B was presented six times before the subject attempted to reconstruct it. If she then failed, she was required to rearrange the series after each presentation. Cases of such failure were numerous enough with both subjects to show that *the interpolation of tests of mastery greatly decreases the number of repetitions necessary for memorising, in the case of persons whose attention is not under practiced control.* For example, Ho. learned with simultaneous exposure and a test after each reading, 8 series of 12 syllables with an average of 4.6

presentations, whereas she required 2.1 extra presentations to learn the corresponding series which had been presented with an average of 9.2 preliminary presentations without tests.

c. In half the experiments of the second subgroup and in half the successive-exposure series in the third subgroup, the subject was required to rearrange the series after each reading or presentation. In the other half every two readings or presentations were followed by a test. Between these pairs of presentations, an interval of only 5 or 6 seconds elapsed. In the third subgroup, in one-third of the simultaneous-exposure experiments, a test followed each reading, in another third a test followed each two readings and in the last third a test followed each four readings. The subject read the syllables or named the cards over twice in about the same time which the experimenter required to present the cards once in succession. Thus two and four readings with simultaneous exposure are equivalent in time respectively to one and two successive presentations. The time required for reconstruction was never less than sixty seconds. In these experiments, rough time records were kept with a stop-watch and proved most important to the correct interpretation of the results. The interpolation of tests reduced the number of repetitions necessary but the tests themselves consumed so much time that the total time which they saved is inconsiderable. Furthermore, the series with simultaneous exposure were learned faster than the series with successive exposure, either because the subject read faster[1] or because spatial associations were promoted.

d. The purpose of the fourth subgroup of experiments was primarily (1) to test the explanation by multiplied tests but incidentally (2) to test the relative ease of naming the units from memory and of reconstructing the series. The material consisted of series of 13 playing cards. Four methods were used. In all these methods, the series-members were exposed in succession in the normal fashion. (1) In the first and third, every presentation was followed by a test; in the second and fourth every two presentations. (2) In the first and second methods, the subject was required to *reconstruct* the series, and

[1] See p. 193.

when she had succeeded in doing so correctly, she was required to recite the series and was prompted when she broke off. The syllables given without prompting were considered as 'right cases.' In the third and fourth methods, the subject was required after every one or two presentations to *recite* the series and was prompted whenever she named a wrong syllable or said 'Ich weiss es nicht.' This process was repeated until the whole series was recited without mistakes. The subject was then required to reconstruct it and the right positions were counted as 'right cases.' Only Ho. served as subject. In this subgroup, the results seem worth schematizing:

Method.	*N.*	*Trials.*	*MV.*	*Presentations.*	*Right cases.*
R.M. 1 trial to one presentation:	10	2.6	0.8	2.6	12.7
R.M. 1 trial to two presentations:	10	1.2	0.3	2.4	12.8
P.M. 1 trial to one presentation:	10	2.4	0.5	2.4	13.0
P.M. 1 trial to two presentations:	10	2.1	0.4	4.2	12.9

P. M. stands for prompting method, although, of course, the method used was by no means the orthodox form of the method of Ebbinghaus and Ephrussi.

The experiments by the reconstruction method show that, as the subject's practice increases, multiplied tests may cease even to reduce the number of repetitions necessary for memorising. (For explanations of this fact see page 167 below). If the number of repetitions is not much reduced by the interpolation of tests then the total learning-time must be greatly increased. In the experiments by the prompting method, in which a new task, that of recitation, was imposed upon the subject, the multiplication of tests reduced the number of repetitions, but figures which are not contained in the table show that the time consumed in learning with a test after every presentation considerably exceeded the time consumed in learning with a test after every two presentations. When a test was given after each presentation, a correct recitation was attained with fewer repetitions than a correct reconstruction.

The experiments of this group as a whole are altogether

inconclusive in regard to the value of spatial associations. As regards the multiplication of tests of mastery they suggest that *what the learner saves in the number of necessary presentations, he may lose in the total time expended in memorising.*

In any case, the experiments were not 'pure.' For when every presentation was followed by a test, each pair of presentations was separated by a much wider time interval than were pairs of presentations between which no test was interpolated. Hence, the experiments with the greater number of tests have the advantage of greater 'distribution of repetitions.' In the next set of experiments this complication is eliminated.

V. The experiments of Group X were devoted simply to testing the explanation *by multiplied tests of mastery.* These experiments were made in the year 1907–1908. A modified form of the method of retained members was employed. The series were English normal series of nonsense-syllables of the length 12. Four different sets of series were used in the experiments. The series were read aloud ten times by the experimenter, in trochaic ryhthm. The reading was regulated by the beats of a metronome. Intervals of one second elapsed between syllable and syllable in each presentation and intervals of 64 seconds between the end of one presentation and the beginning of the next. In one set of experiments, a test was interpolated after every reading; in the other set after every two readings. Several subjects were employed at once. They were required to write the series vertically upon slips of paper ($3\frac{1}{8}$ by $5\frac{3}{4}$ inches) and at the end of each test-period to drop the slips face down into the boxes before them. The time allowed for writing the series was 60 seconds. When no test was interpolated between the presentations, a rather successful attempt was made to distract the subject's attention from the series by reading aloud a novel. This reading was done by an assistant experimenter. Four different novels were used. Among them was *Miser Hoadley's Secret* by Arthur W. Marchmont, which, though execrable trash from a literary point of view, is singularly adapted to hold a subject's attention when read from the beginning in fragments. Three series were learned at each sitting. The

experiments of the two sets were made according to a compensating program.

Two kinds of right cases, 'retained members' and 'sequences' were counted (as in the experiments of Group VII). In these experiments, however, since the series were presented to the ear, the subjects were allowed to substitute for the several elements of the syllables letters which *normally* have the same phonetic value— to write, for example, *caj* for *kaj* and *rise* for *rize*. It seems sufficient to indicate in the table of results only the numbers of retained members. The trend of the sequences is precisely similar. Since all the series were of the same length, averages instead of percentages may be given.

The subjects were G., Ka., Mo., Wi., and eleven beginners. G. had already had a year's practice in learning syllable-series by ear. Ka., Mo and Wi. were members of a second-year class in psychology. Of the beginners, one was identical with Subject 2 in Group VIII. The work of the beginners who worked at the same sittings is massed. G. acted as reader except when she herself and Wi. were subjects. In this case, the syllables were sometimes pronounced incorrectly, and sometimes inconsistently from reading to reading, and moreover, they were often read with such breaks and changes in the rhythm as greatly to disturb G. whose grouping-habit was strong. The results are contained in Table XII.

From these figures, the following conclusions may be drawn:

1. The tests after the first presentation of a new series increased the amount learned on the second presentation.

2. In the method of many tests no extra trial except the first appreciably facilitated the learning of the series. For on comparing the results obtained by the two methods, one finds that the difference between the figures for the trials given after the fourth, sixth, eighth, and tenth presentations is never greater and is often less than the initial difference between the figures after the second presentation. The one set of figures never lags behind the other by more than this initial difference.

3. The numbers of members retained after the same number of presentations approximate in the two methods sufficiently to show that about the same number of repetitions would be

TABLE XII

To Show the Effect of Multiplying Tests in the Process of Memorising.

SUBJECTS.	NUMBER OF PRESENTATIONS FOR ONE TEST.	*N*	AVERAGE NUMBER OF RETAINED MEMBERS WHEN THE NUMBER OF PRESENTATIONS WAS									
			1	2	3	4	5	6	7	8	9	10
G.....	1	18	6.3	10.1	11.1	11.3	11.3	11.5	11.6	11.6	11.7	11.6
	2	18	.....	9.2	.....	11.0	.....	11.5	.....	11.8	.....	11.7
Ka.....	1	16	4.0	6.2	7.7	8.5	9.5	9.9	10.3	10.5	10.8	10.9
	2	17	.....	5.2	.....	7.5	.....	9.0	.....	10.1	.....	10.8
Mo.....	1	16	4.0	5.7	6.9	7.3	8.4	9.0	9.7	10.1	10.7	10.9
	2	17	.....	4.7	.....	6.9	.....	8.3	.....	9.6	.....	10.1
Wi.	1	18	4.0	6.1	7.9	8.9	9.4	10.7	11.3	11.1	11.3	11.4
	2	18	.....	5.7	.....	8.5	.....	9.9	.....	10.4	.....	11.0
4 beginners....	1	36	3.4	5.3	6.6	7.4	8.4	9.0	9.2	9.5	9.8	9.9
	2	35	.....	4.3	.....	6.5	.....	8.1	.....	9.2	.....	9.9
7 beginners ...	1	62	3.8	5.3	6.1	7.2	8.0	8.4	8.9	9.1	9.4	9.6
	2	61	.....	4.9	.....	6.9	.....	8.3	.....	9.1	.....	9.6

required for complete mastery with either method. Thus, it would seem that *when the time which elapses between presentations is the same, whether tests of mastery are interpolated or not, then the mere testing process in itself has little effect in reducing the number of repetitions required for memorising.*

From these last two groups of experiments (IX and X) taken together one may conclude:

First, that the 'explanation by multiplied tests' largely reduces itself to an explanation by one form of 'long intervals' (*see page 10*); *but*

Second, that at least the first test does itself raise the level (*Niveau*) *of mastery, or does alter the learning process in the next presentation or does both, and that experiments by this modified form of the method of retained members are not, therefore, strictly comparable with experiments made by the standard form* (*see page 58*); and

Third, that the interpolation of tests has most value to the poorest memorisers.

This third conclusion requires further discussion. A test involves an extra attentive repetition of that part of the series which the subject already knows. Therefore, two presentations with an interpolated test mean really two complete repetitions *plus* a partial repetition which has an off-set in the impressing of wrong syllables or mistakes of order. To the feeble memoriser the additional opportunity for clinching weak associations is doubtless one great advantage in the multiplication of tests. Thus, one subject in these experiments reported that she found it a help to *write* the syllables as often as possible. This subject memorised slowly, and had a habit peculiar to poor memorisers, that of relapsing in the process of learning a single series.[1] The good or practiced memoriser holds what he has once acquired at least until the whole series is learned, and has no need to keep impressing on himself syllables and sequences which he has once mastered. The feeble memoriser is like a person who is trying, unsystematically and with weak hands, to take up and carry many small packages at one load.

[1] The observation that relapses are peculiar to poor memorisers is based on the examination of many experimental records.

He drops some syllables as he picks up others. A test acts like a careful packing of bundles into pockets during a pause in which no others are taken up. On the other hand, the practiced memoriser grasps the articles in his load firmly at the first and packs them with system as he takes them up, so that pauses for adjustment are unnecessary. For G., the most practiced learner, the help afforded by the tests seemed mainly a matter of saving and profitably distributing her attention. When her knowledge of a series was tested, she located the gaps in it, and on the next presentation could save her energy for filling them in. Thus her attention was certain not to sag in the wrong place. But even this advantage is, like the extra opportunity for clinching associations, unimportant to the practiced subject who learns to test himself even in the course of closely successive presentations.[1] G. distinctly preferred learning by the method with the 'rests.' The first tests involved some exertion, the last few out of ten were simply a bore. As the figures show, toward the last of the series of repetitions, G. could reproduce perfectly rather more series-members with the 'rest-method' than with the other. If the series had been read properly she would have required for perfect mastery by either method far fewer presentations than ten (see the work of G. contained in Tables XI—XIII).

Most of the other subjects agreed with G. in preferring the method with one test for two presentations. The reasons for this preference were not always clearly stated. Thus, two of the beginners reported that they preferred the 'method with the reading' *because* there were two presentations to one test. One beginner, who memorised with marked facility, said that she preferred this method because she was 'not so frightened.' This subject resembled G. in finally accomplishing rather more with the 'rest-method.' Another beginner stated that she preferred this method because in the first of a pair of presentations she could correct mistakes and in the second could learn new syllables. At least two of the subjects preferred the method

[1] With G. this process is partially visual and is *somewhat* like comparing an imperfect copy of a series of colored spots with an original, and filling in the blank spaces.

with the many tests. Mo. reported that during the novel-reading, in the other method, her attention wandered and was with difficulty brought back to the series at the next presentation. These statements of preference were made without knowledge of the results obtained by the two methods.

To recapitulate again, in brief, multiplied tests involve three advantages for the learner:

1. They interpolate considerable intervals of time between successive presentations. Whatever else these intervals accomplish (see page 202 below), they at least relieve the breaking-strain upon attention.

2. They give the learner a special opportunity—if he needs it—to hammer down the pile-like foundations upon which his knowledge of the series is gradually built up.

3. They give the learner a special opportunity to find the gaps and weaks places in his knowledge.

Nevertheless, these advantages do not prove that multiplied tests save *time* in learning the series.

An incidental observation in connection with this group of experiments is the following: Nearly all the subjects, including G., were inclined, at least until a series was prettly well mastered to write down the last members first. The syllables were not in general, written in order from last to first, but the last few were written first and in their proper order. With G., at least, this reproduction depended on the auditory-memory after-image. The procedure was for G. distinctly disadvantageous although it is the line of action which subjects in the method of retained members take on impulse. By the time the subject G. was ready to write the first members of the series she had very often forgotten them, either owing to the interval which had elapsed since they were presented or owing to retroactive inhibition. The first members of a series tend strongly to recall the later but the later members have much less power over the earlier and it would even seem that the later may actually inhibit the earlier.[1] It is, therefore, prudent to take no risks

[1] Even granting the importance of the 'initiale Reproductionstendenz.' See Müller and Pilzecker, *op. cit.* pp. 199–204.

in regard to the initial members of a series which is rapidly presented and which must be reproduced and not merely reconstructed. (See page 207.)

VI. The experiments of the eleventh group are few in number but are nevertheless important. It appeared highly desirable to probe the explanation by multiplied tests with experiments on G. by the reconstruction method, and to do so in such a way as to isolate the effect of the tests as such from the effect of the intervals which they of necessity interpolate between presentations. The effect of multiplying tests in the reconstruction method must be the greater because the process of reconstruction must foster the 'criss-cross' (supplementary intrinsic) associations whose importance is peculiar to this method. The experiments of this group have been made in the month before the Christmas holidays of 1908 and are the most recent experiments covered by this monograph. Colors were chosen as material because they are hard for G. to discriminate and therefore make especially important such opportunities for review and comparison as are offered in the tests. The series consisted of 32 members which were arranged in four horizontal rows of eight each. The placing rules were the same as in the older experiments but no importance was attached to certainty of correctness. The first member of the series was not handed to the subject as the first so that the series were *bona fide* series of 32 members. Three sets of experiments were made according to a compensating program. In the first set, the procedure was practically normal except that eight minutes were always made to intervene between the end of one presentation and the beginning of the next, whether the whole of this period was required for the reconstruction and recording of the series or not. In the second set of experiments, two presentations were made in immediate succession whenever one presentation would be made by the normal method, and eight minutes were made to intervene between the end of one pair of presentations and the beginning of the next. The procedure in the third set of experiments differed from that in the second, only in the interpolation of eight minutes, unoccupied by any attempt at reconstruction,

between the members of each pair of presentations. Symbolising *presentation* by *P.*, *trial* at *reconstruction* by *T.*, *recording* by *R.*, and *vacant interval* by *V.*, and representing minutes in round numbers by numerals in parenthesis one may schematise the three procedures as follows:

1. P (2) T (5) R (3) P (2) T (4) R (2) V (2) P (2) T (4).....
2. P (2) P (2) T (5) R (3) P (2) P (2) T (4) R (2) V (2).....
3. P (2) V (8) P (2) T (5) R (3) P (2) V (8) P (2) T (4).....

The third procedure was called for brevity the method of 'double presentations with rests' and the second the method of 'double presentations without rests.' The subject spent the vacant intervals in chatting with the experimenter. The times occupied by the various phases of the experiment were kept with a stop-watch; the color-squares were presented rather more quickly than at the rate of one per four seconds; two minutes is an ample representation of the time occupied in presentation. Eight minutes was approximately the time required for the first reconstruction and recording of the series; therefore, in order that the intervals might be uniform, eight minutes were allowed to elapse whenever an interval was introduced between presentations. We may safely say that the reconstruction of the series took at least twice as long as the presentation. In reporting experiments of this character, only round numbers seem required for the time-estimates.

The results are as follows:

Method.	*N.*	CORRECT RECONSTRUCTION.			PERFECT RECONSTRUCTION.			*RS%.*	
		Trials	*MV.*	*Pres'ns*	*Trials*	*MV.*	*Pres'ns*	*W* = 1.	*W* = 2
Normal.....	10	3.3	0.8	3.3	4.0	0.8	4.0	19.0	71.0
Double pres'ns without rests	10	2.3	0.4	4.6	3.1 *N*=9	0.8	6.2	.....	56.5
Double pres'ns with rests....	10	2.3	0.4	4.6	2.3	0.4	4.6	....	58.4

From the figures for the first and third methods, it would seem that multiplying tests saves presentations, but it would seem that presentations are not saved to the extent that trials

are lavished. In any method in which the presentations go in pairs, the possibility always exists that the last presentation of any series was unnecessary, and even as the figures stand the numbers of presentations approximate more closely than the numbers of trials. In these two procedures the intervals between presentations was the same whether a trial had been given or not. If the figures for the second procedure are not influenced by the accidental difficulty of the series,[1] then the lapse between presentations of the time ordinarily occupied by reconstruction reduces the number of presentations necessary to the perfect reconstruction of the series whether a trial has been given or not. Thus, this small group of experiments leads one to the same conclusions as those suggested by the preceding group. The advantage of multiplied tests is in part explained by the time-interval interpolated between presentations. Nevertheless, the learner does make some actual advance through the testing process. But on the other hand, trials have no magical effect in reducing the number of presentations required. The figures obtained by the several methods are not very different, and in these last experiments with G., the number of presentations necessary for learning is much more uniform than the number of trials.

G. greatly preferred the method of double presentations without rests to either of the others used in the last group. This method was quick on the one hand, and on the other eliminated the irksome guessing of a reconstruction after only one presentation. The average time occupied for learning a series by these three methods may be estimated, on the basis of the round numbers of minutes given in the scheme, as 29,23.6 and 42 minutes respectively for a correct reconstruction, and as 36, 33.2 and 42 minutes respectively for a perfect reconstruction. These times include all the intervals essential to the different procedures, and also the time occupied by the last reconstruc-

[1] The facts must again be noted that when series of 30 or 40 members are given the number of series given must be relatively small, and that long series must be given by this method if, with a practiced subject, the numbers of presentations are not all to approximate to unity. The learning of 30 series of 32 members represented a time-expenditure of about 18½ full hours.

tion, but not the last recording-time. It is noticeable that the method which makes the worst showing as regards the number of presentations, makes the best showing both as regards the total time required and as regards the preference of the subject.[1]

VII. The experiments of Group XII are the most important of the experiments which were made to find an explanation of the peculiar results obtained by the reconstruction method. They are the most important because they were the most extensive, and because they go farthest toward furnishing the explanation desired.

In this group of experiments four questions are at issue. The first of these questions belongs only to the first subgroup of experiments but it may be enumerated among the four because it determined the method of the first subgroup, and the method of the first subgroup determined the method of the other subgroups.

This first question was as follows: What could G., who could memorise such extraordinarily long series by the reconstruction method, accomplish with the method of Ebbinghaus and of Müller and Schumann? The experiments of this first subgroup followed, logically and chronologically, upon the work of the fourth year of the reconstruction experiments. This fourth year had been devoted to the experiments with parallel use of smells, colors, and nonsense-syllables, and to the control-experiments whose object was to determine how far G. in memorising series-order memorised series-members as well. It was proved that G. could master very long series of nonsense-syllables even rather better than very long series of smells and of colors. It was shown, moreover, that when she had mastered the order of a smell or syllable-series, she could also name nearly all of the smells and syllables in order. The question then arose as to whether her achievements in learning long series were conditioned by the reconstruction method itself.

[1] The eight-minute periods of rest are inc luded in the learning-time because they both postponed the completion of the learning and had an effect on the number of presentations necessary.

In the subgroup of experiments with which we are now dealing, the first subgroup of the twelfth group, four different series-lengths including the length 81, were used. The syllables were presented to the ear instead of to the eye in order that the conditions might be as different as possible from those of the experiments with syllables by the reconstruction method. For the sake of uniformity, this auditory mode of presentation was retained throughout the whole of the twelfth group of experiments.

The method of complete memorising was chosen for the experiments of this twelfth group, not merely for the sake of bringing G.'s work into comparison with that of Ebbinghaus and of the Müller and Schumann subjects, but also for the sake of studying time intervals. In our own reconstruction method the time required for rearrangement cannot well be controlled, although with the use of suitable apparatus it is perfectly possible to vary accurately the intervals at which the series-members are presented. It seemed to us that the effect of time-intervals could, for our special purposes, be studied satisfactorily only with a method in which oral reproduction at a given rate is required of the subject. Therefore, since we wished results in terms of repetitions necessary for complete memorising, we were confined by the conditions of our problem to the Ebbinghaus method with only minor variations. The exact nature of the interval-problem with which we were concerned in this group of experiments can best be stated after two other problems have been formulated.

The second question at issue is as to whether or not the degree to which recitation enters into the several repetitions of a series makes much difference in the number of repetitions which are necessary for learning it. The meaning of repetition in the method of complete memorising must be emphasised and should be kept clearly in mind. A repetition is a traversing or a going-over of the series and may consist partly of presentation and partly of recitation. Only the very first and last repetitions must be all the one or the other: the first repetition (really not a repetition in the strictest sense) *must* be all presentation; the last repetition must be all recitation. Experimenters by this method

assume that presentation and recitation have the same value for learning; that is to say, they assign the same value to a repetition which consists three-quarters of recitation and one-quarter of presentation and to a repetition which consists one-quarter of recitation and three-quarters of presentation. The question is whether or not the same value ought to be assigned to the presentation and recitation. One of the criticisms made by Münsterberg upon the method described by Ebbinghaus in *Ueber das Gedächtnis* was to the effect that the repeated attempts to recite a series which was incompletely learned introduced into the procedure an element difficult to control, and that recitation-repetitions and presentation-repetitions ought not be brought into simple coördination.[1] Müller and Schumann made special experiments to determine whether one of their subjects (Dr. Pilzecker) did or did not, by dint of his partial recitations of the series from the beginning, make more lasting associations between the syllables in the first half than between those in the second half of series. The result was negative, but has, of course, only an individual value.[2] Furthermore, it does not follow from the case of this subject, even if it be typical, that attempts at recitation do not diminish the number of repetitions necessary to memorise. For that strengthening of associations which is involved in the first perfect recitation of a series *may* not be the same kind of strengthening which insures the tenacity of associations even for twenty-four hours.

To answer the second question, that is, to test the value of recitation in learning we introduced prompting into some of our experiments with the method of complete memorising. In some sets of experiments, the orthodox method of complete memorising was used without any variations except in the matters of auditory presentation and varied time-intervals and in the fact that the subject was *required* to try to recite the series as soon as it had been presented once. As soon as the subject made a mistake or failed to name a syllable in a given length of time after the naming of the next preceding, the experimenter named the proper syllable and then presented the rest

[1] *Beiträge zur experimentellen Psychologie*, 4, p. 124.
[2] Müller and Schumann, *op. cit.*, pp. 187–190.

of the series without giving the subject another chance to recite until she had read to the end. The subject was then required to try again, and the rest of the procedure was repeated until the whole series was recited without mistakes and without hesitation beyond the limits of a certain time interval. This method will be called our *standard* method of complete memorising. In the other sets of experiments, the method was exactly the same except that the subject was prompted whenever she hesitated or made a mistake and was then allowed to recite until she again broke down. This method will be called the *prompting* method of complete memorising. The purpose of the prompting variation is indicated in the following assumptions: first, that if partial recitation in itself, that is, apart from the fact that it involves a partial repetition or traversing of the series-sequences, reduces the number of repetitions necessary for memorising, then the subject should learn more quickly by the prompting method of complete memorising than by the standard method; and second, that if recitation, as such, facilitates learning by the method of complete memorising then the multiplied tests of our reconstruction method must have been a factor in reducing the number of repetitions necessary for memorising series-order.

The third question of the group of experiments with which we are dealing is concerned with the emotional disturbance which the subject may feel in the method of complete memorising as the result of having to recite the series at a rapid rate or even of having to repeat it at any fixed rate at all. Can the number of necessary repetitions be decreased by allowing the subject a longer time or unlimited time in which to recite the series? This question bears upon the validity of the explanation of the easiness of the reconstruction method by leisurely recall, that is, by the fact that the subjects were allowed all the time they wanted for the rearrangement of the series. The question cannot be solved without altering time intervals in recitation and yet it is not concerned at all with lapse of time *per se*.

The fourth question, on the other hand, has to do only with lapse of time as such. It deals with the effect of altering the

time which elapses between each series-member and the next (between *a* and *b*, *b* and *c*, *c* and *d*, and so on) in traversing the series in either fashion, presentation or recitation. It waives any possible difference between presentation and recitation. For the sake of clearness in discussion, it should be noted that the experiments of this present group are not concerned, like those of the last group, with the interval which elapses between the end of one complete repetition and the beginning of the next (the interval between *z* and *a*). This interval in the first two subgroups of the experiments of the present group was not varied at all, and in the last two subgroups it was varied very slightly.

In brief, the four-fold object of the twelfth group of experiments was to gauge the degree to which G.'s achievements in learning very long series were conditioned by the peculiarities of the reconstruction method (the first question), and to test the validity of three theories in regard to the small number of repetions necessary for learning series-order by our normal reconstruction method (the second, third, and fourth of the questions outlined above). These theories are the explanations *by multiplied tests*, *by leisurely recall*, and *by slow rate of presentation*. (See pages 9 and 10.)

The tables of results must be preceded and will be followed by sundry descriptive and explanatory details, The experiments, as already indicated, fall into four subgroups. The experiments of the first two subgroups were made in the academic year 1905–1906; those of the last two subgroups in the spring of 1908 (after the experiments of Group X). The subject in the first and third subgroups was G.; the subjects in the second and fourth subgroups were beginners. In the first two subgroups, series of the hit-or-miss type and of different lengths were used; in the last two subgroups, English normal series of the lengths 12 and 18. In the first two subgroups, the intervals between the syllables in presentation and recitation were timed roughly with a watch; in the last two subgroups, both presentation and recitation were timed with a metronome In the first two subgroups the series were read without rhythm, and the subjects were allowed to recite the series as fast as they

pleased even in cases where they were also allowed to name the syllables at five-second intervals. The experimenter, however, named the next syllable at once if the subject hesitated beyond the limit of the interval allowed. In the last two subgroups, those series which were presented at the rate of one syllable to a second, were read (not always perfectly) in trochaic rhythm. The series which were presented more slowly were not read rhythmically. In all cases, however, with one exception which will be stated later, the subjects were required to name the syllables upon certain metronome-beats—on successive beats, on every second beat, or on every fourth beat as the case might be. The metronome was so set as to beat once to a second. Verbal counting of a small even number of beats is not necessary, after the subject has once put rhythm into the beats. "Tick-tack, tick-tack" says the clock in the nursery-rhyme and both subject and experimenter might watch as well as listen to the metronome if they chose. If a subject failed to name the proper syllable on the proper beat, the experimenter named it, not on the first, but on the second beat afterwards. That is to say, if the syllable was due on a 'tick-beat' it was named on a tick-beat; if it was due on a 'tack-beat' it was named on a tack-beat. Thus, the rhythm was not broken by the prompting. Rhythmical recitation, however, was not *required* of the subjects. In the first two subgroups the time between presentations was not intentionally varied although it was not kept rigidly uniform, and it sometimes amounted to a minute, or even on rare occasions, with long series, to two or three minutes; but any serious interruption of the subject's attention caused the series to be discarded. In the third and fourth subgroups the time between repetitions was carefully regulated and (except by trifling accident) never exceeded nine seconds. Details will be given below. In the first two groups of experiments the first syllable was named by the experimenter at the beginning of every recitation as a 'starter'; in the last two groups it was not.

In the experiments of the third and fourth subgroups, two experimenters were employed. The first experimenter gave

her whole attention to reading the series and preserving the proper intervals; the second experimenter recorded the points at which the subject failed and the number of repetitions required. Tables XIII–XV should here be examined.

In explaining Tables XIII to XV it remains merely to outline in words the different sets of experiments and to indicate the method by which the figures for the 'learning-time' were obtained. As in the earlier experiments, *L* stands for series-length; *N* for the number of series in the set; *W* for the average number of repetitions required for memorising and *MV* for mean variation.

The experiments of the first subgroup are covered by the first part of Table XIII. The subject was G. The subgroup includes twenty-four sets of experiments. The experiments of these sets were made according to a compensating program. Series of four different lengths were used in six different ways. That is to say, there were four different arrangements of intervals with the standard method and two different arrangements with the prompting method,[1] making six different procedures in all.

The second subgroup of experiments is covered by the latter part of Table XIII. Eight beginners served as subjects. Other beginners served as experimenters. The results are massed according to the principles stated on page 49.[2] Eight different sets of experiments were made according to an alternating program. Two different series-lengths were used in four different ways, that is, with two different methods and with two different arrangements of intervals under each method.

The experiments of the third subgroup fall into four different divisions which were made one after another. In each division two sets of experiments were made according to a compensating program. The subject was G. The results of the first divi-

[1] We may perhaps be permitted in this section to call this latter method for short the prompting method, although it is not the prompting method proper. (See pp. 55.)

[2] In these experiments, the results were massed not only in the ordinary way, but also by averaging the averages of individuals. The difference between the two sets of results is surprisingly small, and does not alter in the slightest degree the conclusions to be drawn.

TABLE XIII.

To Show the Effect of Prompting and of Alteration of Time Intervals between Series-Members in the Method of Complete Memorising

Experiment-Group XII, Subgroups 1 and 2

SUBJECT.	METHOD.	INTERVALS.		*L*	*N*	*W*	*MV*	*L*	*N*	*W*	*MV*	*L*	*N*	*W*	*MV*	*L*	*N*	*W*	*MV*
		Pres.: Secs.	Rep.: Secs.																
G.....	Standard	5	5	11	3	1.7	0.4	21	4	3.8	1.8	41	4	4.0	0	81	4	8.8	1.8
		1	1	11	4	5.8	0.4	21	4	10.3	2.3	41	4	14.0	2.0	81	4	35.3	7.8
		5	1	11	4	3.5	0.8	21	4	4.5	0.8	41	4	10.5	6.0	81	4	17.3	9.3
		1	5	11	4	3.3	0.8	21	4	5.3	1.9	41	4	7.5	2.5	81	4	16.5	2.0
	Prompting	5	5	11	3	2.3	1.1	21	4	3.5	0.5	41	4	4.3	0.4	81	4	9.8	1.4
		1	1	11	3	5.0	0.7	21	4	5.8	1.3	41	4	10.3	1.8	81	4	20.0	5.5
Eight beginners	Standard	5	5	11	75	4.1	1.3	21	75	6.9	1.9	....	.....	.....	.....	....	.....	.....	....
		1	1	11	73	6.8	2.3	21	73	12.5	4.3	....	.....	.....	.....	....	.....	.....	....
	Prompting	5	5	11	75	4.2	1.2	21	75	7.4	2.1	....	.....	.....	.....	....	.....	.....	....
		1	1	11	75	5.7	1.6	21	75	9.8	3.1	....	.....	.....	.....	....	.....	.....	....

TABLE XIV

To Show the Effects of Proptming in the Method of Complete Memorising.

Experiment-Group XII, Subgroup 3 and 4

Division 1. Intervals in Presentation and Reconstruction: 4 Seconds

Subject.	*Method.*	*L*	*N*	*W*	*MV*	Mean learning time: secs.	Mean time per repetition: secs.
G.....	Standard	18	20	4.9	1.6	341	70
	Prompting	18	20	3.8	0.8	278	74
B.1	Standard	12	20	5.4	1.5	246	46
	Prompting	12	20	4.9	1.1	244	50
B.2	Standard	12	20	8.6	3.8	394	46
	Prompting	12	20	7.6	2.7	391	51
B.3.....	Standard	12	15	8.9	2.2	406	46
	Prompting	12	15	10.0	3.6	535	54
B.4.....	Standard	12	20	6.8	2.0	311	46
	Prompting	12	20	6.5	1.9	332	51

sion stand at the beginning of Table XIV. The two sets of experiments differ only in the methods used, the standard and the prompting methods. The series were all of the same length and the same (four-second) intervals were used. The results of the second, third, and fourth divisions occupy the first part of Table XV. The sets of experiments differ only in the matter of intervals. The series were all of the same length, and the standard method was used throughout. In the second division, all the series were recited slowly, that is, at four-second intervals, but half were presented slowly and half rapidly, that is, at one-second intervals. In the third division, all the series were presented rapidly, but half were recited rapidly and half slowly. In the fourth division half the series were presented and recited slowly and half were presented and recited rapidly.

The experiments of the fourth subgroup fall into three divisitions. The subjects were the beginners who are symbolised by B. with numbers from 1 to 10. Other beginners served as experimenters. The experimental programs were of the compensating type. The experiments of the first division are exactly analogous to the first division of the third subgroup. The results are included in Table XIV. The experiments of the

TABLE XV.

To Show the Effect of altering the Time-Intervals between Series-Members in the Standard Method of Complete Memorising

Exp.-Group XII, Subgroup 3, Divs. 2–4 and Subgroup 4, Divs. 2 and 3.

Subject.	INTERVALS.		*L*	*N*	*W*	*MV*	Mean learning time: secs.	Mean time per repetition: secs.
	Presentation: secs.	Reproduction: secs.						
G.....	4	4	18	**18**	3.7	0.9	259	69
	1	4	18	**18**	6.6	1.5	211	32
	1	4	18	**18**	6.5	1.0	199	31
	1	1	18	**18**	10.8	3.0	203	19
	4	4	18	**18**	4.3	0.9	299	70
	1	1	18	**18**	10.4	1.2	196	19
B. 5.....	4	4	12	**20**	6.2	0.8	281	46
	1	4	12	**20**	9.9	2.8	251	25
B.6.....	4	4	12	**20**	5.9	1.7	269	46
	1	4	12	**20**	8.4	1.6	221	26
B.7.....	4	4	12	**20**	5.3	1.4	242	46
	1	4	12	**20**	9.4	2.4	224	24
B.8.....	2	2	12	**20**	9.1	1.8	.....	24
	2	.....	12	**20**	8.7	2.1	.....	23.4
B.9.....	2	2	12	**20**	12.0	4.0	.....	24
	2	.....	12	**20**	9.0	1.7	.....	28.2
B.10.....	2	2	12	**20**	9.0	5.0	.....	24
	2	.....	12	**20**	6.1	1.4	.....	28.2

second division are exactly analogous to those of the second division of the third subgroup. The results are found in Table XV and are there labelled as the work of beginners 5 to 7. The experiments of the third division differ from all the other experiments. The results stand at the end of Table XV and are marked as the work of beginners 8–10. In both the sets of experiments made upon each subject, the syllables were pre-

sented at intervals of two seconds. In one set, however, the subjects were required to recite the syllables at this same rate whereas in the other set they were not in any way limited in the time of recitation except that they were required to pronounce the syllables on metronome-beats, and therefore could not recite them at a faster rate than one per second. The time required for reproduction was measured with a stop-watch.

In the first two subgroups (Table XIII) the time between repetitions was not intentionally varied although it was not kept rigidly uniform. The interval often amounted to a minute or even sometimes to two or three minutes in the case of the very long series. In this case the subject G. occasionally suffered from the same nervous disturbance which was involved in the reconstruction of the long smell series; and she was accustomed to delay the beginning of a recitation until violent heart-beat subsided. In the third and fourth subgroups (Tables XIV–XV) the time between repetitions was carefully regulated. When presentation and recitation were both slow, that is, when the syllables were named on every fourth metronome-beat, the experimenter gave the signal 'Now' on the fourth beat after the one on which the series ended, and the subject was required to name the first syllable on the fourth beat after the signal. In this case, there was no rhythm to be preserved. When both presentation and recitation were fast, that is at the rate of one syllable to a beat, the experimenter said 'Now' on the first beat following the last syllable and the recitation began on the second beat after the signal. Thus, in the case of the 'slow-slow' series the interval between presentations was eight seconds and in the case of the 'fast-fast' series was three seconds. The last number of seconds was uneven because the series ended on a 'tack-beat,' and yet the rhythm required that the signal 'Now' should be given and that recitation should be begun on a 'tick-beat.' In the case of the fast-slow series, the interval was seven or nine seconds, (seven seconds by a rule, not always carried out). When the syllables were named on every second beat, the signal was given two seconds after the last syllable-beat. If the recitation-time was limited the subject was required to begin on the second beat after the signal; if the time was not

limited she might begin either on this beat or after it as she chose. Thus the total interval was at least four seconds.

The difference in these intervals is very important as regards the subject's emotional condition, almost more important than the intervals within the series. The subject who is liable to stage-fright finds it all-important to get a recitation once under way. But aside from its emotional effect the writer believes that the difference in these intervals may be almost disregarded, since the intervals themselves were largely occupied in the counting of the beats (not necessarily a verbal counting).

Except in the case of the experiments in which the recitation-time was unlimited, the learning-time for each series was calculated on the basis of the length of the intervals, of the number of repetitions necessary, of the number of times the subject was prompted, and also, for the series in which the presentation-intervals differed from the recitation-intervals, on the basis of the points at which the subject failed in the various repetitions. The intervals between the repetitions were left out of account. One imperfect repetition of a series of 18 members, with four second intervals by the standard method, occupies 70 seconds since there are 17 four-second intervals and an extra two-second interval at the point at which the subject fails. If five repetitions are required the learning time is 348 seconds, that is, 4×70 seconds *plus* the 68 seconds consumed in the first presentation. In these experiments the final repetition, which consists entirely of recitation, was not counted in the number of repetitions necessary for memorising; therefore to make the results comparable with those of Müller and Schumann 1 must be added to all the numbers given under *W* in the tables. A single repetition of a series of the same length at the same intervals, if the subject were prompted five times, would consume 78 seconds since 5 extra two-second intervals must be added to the 17 four-second intervals. Further details seem unnecessary.

From the results of the twelfth group of experiments as a whole, the following conclusions may be drawn:

1. The subject G. *did succeed* in learning series of 41 and of 81 nonsense-syllables by the method of complete memorising

even when the syllables were presented and recited approximately at one-second intervals. To learn a series of 81 members by this method and at this rate required about three quarters of an hour. To learn a series of 81 members by the same method when the syllables were presented and recited at five-second intervals required about an hour. To learn a series of 81 syllables by the reconstruction method required, exclusive of the last rearrangement, about an hour and a quarter. We may, therefore, conclude without hesitation that *after the practice obtained with the reconstruction method* (three years and a half in all and one year with nonsense-syllables) *G. could master series of syllables in an even shorter time by the method of complete memorising, whether the members were presented rather more slowly than the syllables in the reconstruction method or about three and a half times as fast.*

Unfortunately, it can now never be determined whether or not the technique by which the subject performed these feats could have been acquired by any other method than our own reconstruction method with its slow presentations and its premium on spatial associations. The subject herself believes that she would *in time* have acquired a very similar technique with the method of complete memorising, since she had always (so far as she can remember) been especially prone to making and to holding fast by spatial associations.[1] In any case, the subject's procedure in learning by the method of complete memorising was certainly closely similar to her method in memorising by the reconstruction method. She saw the color-images (see pages 106 and 110) of the syllables in one long line running from left to right sometimes at reading distance, sometimes at about the height of the table on which she had been wont to arrange the syllable-cards and colors. The line in the case of longer series

[1] For example, the rules and paradigms of the Greek grammar always appear in definite page-positions, although examination of the grammar first and most diligently conned shows that they have often shifted out of their original positions. The rule for 'conditions contrary to fact' occupies in the grammar the middle of the left-hand page; the subject sees the rule at the bottom of the right-hand page. Here among dusky lines within a white margin the colors of *εἰ* and the *ἄν* glimmer in definite positions. The two breathing-marks and the accent to *ἄν* are black and are the only characters visualised.

ran further to the left and to the right than in the case of the shorter series. The subject knew at starting the length of the series and located the first syllable according to the series-length. In the case of the long series, the line was apt to tilt somewhat, lying outward at the extreme left and then running inward so that the right end sometimes seemed to be a little behind the subject.[1] The line was not all seen at once but the several syllables had places in it. The syllables were massed into unit-groups of four except that the last two in every ten syllables, after twenty, paired off by themselves. The unit-groups were themselves grouped in the longer series; the first larger group included twelve, the next eight, and all the rest contained ten. The subject read the syllables off from the colored spots with the aid of auditory and tactile images. The points of greatest danger were at the junctures of the groups. While reciting each group of four the subject looked on for the initial of the next. If she could not see it, disastrous perturbation nearly always set in. Special attention was, therefore, given to 'locking together' the terminal member of one group with the initial of the next. The chief difficulty which the subject experienced when the series were presented rapidly was in getting the syllables quickly and correctly into their groups. The transcending of this difficulty was the chief effect of practice.

The experiments of the third subgroup were made after an

[1] The character of the line may have been determined by the subject's number-form. All the lower numbers lie on a line from left to right—the pinkish-brown of the eight, the green of the nine, and so on, flashing out in turn—but numbers over a million are thought of with reference to one another as lying on a line running forward at right angles to the first. The word *eternity* is gray. The subject thinks of eternity as a gray band running forward and backward like the higher numbers and always on her right. Past time is in front, future time is behind. (She has her back toward the future!) The present is in line with her right shoulder. Both ends of the line are lost in masses of gray cloud. Childish as these images are, they show how ingrained with this subject are pseudo-chromæsthesia, symbolic visual representation, and spatial projection, and how the three tendencies intermingle. The *Ding an sich* is a pink and white ball alone in a gray mist. *Sich* is pink. The *Anstoss* of Fichte is a brownish wall against which the vaguely ball-like ego bounces. *Anstoss* is brown, on the whole. Images undoubtedly become more stereotyped when they have once been described in words, but none of those just mentioned were deliberately formed.

interval of twenty months during which the subject G. had had very little practice. Her self-observation showed that she was somewhat out of practice. The position of the colored spots was less distinct and less fixed, the grouping was less easy and less marked, and the subject grasped more at auxiliary (mnemonic) associations than ever before in memorising any kind of material. The numerical results also show a slight fall in the practice-level. (The results for the series-length 21 in Table XIII should be compared with the results for the series-length 18 in Tables XIV and XV. Of course, the comparison should be made only between sets of series learned by the same method with parallel arrangement of intervals.) These experiments of the third subgroup are the last experiments made upon G. except the short sets of control-experiments described on page 146 and the experiments of Group XI. The latter show but slight loss of practice as compared with the earlier color-work.

The second, third, and fourth conclusions all relate to explanation offered for the peculiar results of the reconstructon method. (See pages 173 and 176.)

2. Series which were repeated at the rate of one syllable *per second* were learned with a smaller number of repetitions (and in a shorter total time) by the prompting than by the standard method of complete memorising. In the case of series which were repeated at the rate of one syllable every four or five seconds the prompting method has no constant advantage. Even in the case of rapid repetition, its advantage in the series of eleven members is very slight. We may, therefore, infer that *with the series-lengths ordinarily used in the method of complete memorising the degree to which recitation enters into the repetitions is unimportant, but not quite immaterial when the question at issue is delicate.* But we may also conclude *that the results of these experiments are purely negative as regards the value of the multiplication of tests in the reconstruction method* in which presentation is so very leisurely.

The details of the case in the experiments which we are now considering are as follows: The beginners in the second subgroup of experiments (see Table XIII) learned the slowly repeated series with almost as small a number of repetitions by

one method as by the other. Nevertheless, a uniform, though slight advantage lies with the standard method. In Subgroup 4 (see Table XIV), three of the four beginners learned the series, all slowly repeated, with a slightly smaller number of presentations by the prompting method; with Beginner No. 3 the case was reversed. This subject complained that the prompting 'worried' her. Some of the beginners also in Subgroup 2 complained of such disturbance. Distraction produced by the prompting may explain the advantage which in Subgroup 2 rests with the standard method. G. learned the slowly repeated series of length 18 (see Table XIV) and of 21 (see Table XIII) with a rather smaller number of repetitions by the prompting method, but learned the slowly repeated series of lengths 11, 41 and 81 (see Table XIII) with a smaller number of repetitions by the standard method. (By the expression 'slowly repeated series' is meant series which were both presented and recited at four or five-second intervals.) G. was not distracted by the prompting. The reason she learned the longer series, when slowly presented, with a smaller number of repetitions by the standard than by the prompting method is of a very different kind. This subject was apt to fail from 'nervous excitement' toward the beginning of long series even when, or perhaps specially when, she had mastered the latter part. She particularly disliked to hear the experimenter read, one by one, at long intervals an interminable array of syllables which she had already memorised. Therefore, in reciting the 'long and slow' series by the standard method, she exercised supernormal attention, an agonised self-command.

The advantage of the prompting method in the case of the rapidly repeated series seems to be in the attention and swift apprehension demanded under conditions in which it is difficult to apprehend at all and consequently difficult to attend. In the standard method when the subject has once failed, he may 'sit back' (often literally) and let the rest of a rapidly repeated series pass over his helpless head.

3. *The allowing of unlimited time for recitation and even the lengthening of the intervals at which the subject was required to recite the syllables greatly reduced the number of repetitions*

necessary for learning the series. This fact can, of course, be most clearly seen by comparing sets of series presented at a uniform rate. (See Table XV, the work of G., represented in the third and fourth lines and the work of Beginners 8 to 10.) The reduction in the number of repetitions required for memorising can scarcely be laid entirely to the fact that the subjects traversed the syllables more slowly when leisurely recall was allowed. For the average time spent upon each repetition shows that most of the syllables were actually passed over at the rate prescribed for presentation, either because the subject actually recited only a few of the syllables at each unsuccessful attempt to reproduce the series, or because she preferred to recite at the rate prescribed for presentation. When with G., for example, the recitation-intervals were of four seconds and the presentation-intervals were of one second then 31 seconds on an average were spent to a repetition. This number of seconds, spent upon a single repetition, would imply 3 four-second intervals, 1 six-second interval, and 13 one-second intervals; as an average, it implies that only the first four or five syllables were recited and that the rest were presented. As a matter of fact, the lengthening of the time spent in recitation actually shortened the total time consumed in learning the series. This saving of time could not have been secured unless the decrease in the number of repetitions had been great in proportion to the increase in the time occupied by each repetition. We may, therefore, conclude that *timing, and especially the requiring of rapid recitation, raise the number of repetitions necessary in the method of complete memorising. From this conclusion we may infer that the unlimited time allowed by our method in rearrangement is an important factor in enabling the subject perfectly to reconstruct series by our method after a very small number of trials.*

4. *Decreasing the rate (increasing the intervals) at which the syllables were presented greatly decreased the number of repetitions necessary for learning the series.* This fact is brought out unequivocally by the whole trend of Tables XIII to XV. We may, therefore, conclude without hesitation that *the slow rate of presentation is a potent factor in reducing the number of repetitions necessary for memorising by our reconstruction method.*

Nevertheless, the 'explanation by slow rate of presentation' is not altogether sufficient to interpret the difference between our results with the reconstruction method and the Ebbinghaus and Müller-Schumann results with the method of complete memorising. Two facts must be put clearly side by side—namely, (1) that it is considerably 'easier'—as measured by the number of necessary repetitions—to learn serial order by our reconstruction method than it is to learn 'slow' series by our method of complete memorising, and (2) that it is easier to learn 'fast' series by our method of complete memorising than it is by that of Ebbinghaus and Müller. These two statements must now be justified. In the first place, even with a somewhat slower rate of presentation, with about the same number of members in the series, and at approximately the same practice-level, the number of presentations necessary for learning series by our method of complete memorising somewhat exceeds the number necessary for learning series-order by the reconstruction method. The beginners whose work is represented in Table XIII learned 75 series of 11 nonsense-syllables repeated at the rate of one syllable per five seconds with an average of 4.1 repetitions and learned 75 series of 21 syllables repeated at the same rate in 6.9 repetitions. But the beginners whose work is represented in Table VV perfectly rearranged 52 series of 12 syllables (series of exactly the same type) presented at the rate of one syllable every three and a half seconds with an average of 2.4 repetitions and rearranged 58 series of 18 members with an average of 3.5 repetitions. The relatively small number of repetitions required by our reconstruction method as compared with our own standard method of complete memorising could readily be shown by still other figures. In the second place, even our unpracticed subjects required for the learning of series of 11 and even of 21 syllables, repeated by our standard method of complete memorising at the approximate rate of one syllable a second, a distinctly smaller number of repetitions than Ebbinghaus and the Müller and Schumann subjects required for learning series of 12 syllables repeated by their method at the rates respectively of one syllable to every two-fifths and to every four-fifths of a second. Ebbinghaus required from '14 to 16 repeti-

tions,'—including the last, successful recitation; the Müller and Schumann subjects required about the same number as Ebbinghaus or required a slightly higher number of repetitions for learning wholly new series. Our own beginners, who work appears in Table XIII, learned 73 'fast' series of 11 members with 7.8 repetitions and 73 'fast' series of 21 members with 13.5 repetitions, including the fully successful recitation. Our intervals in the 'fast series' were 5/2 as long as the Ebbinghaus intervals and 5/4 as long as the Müller-Schumann intervals were in general, yet at least two considerations prevent us from explaining the difference in the results by the difference in the rate. One consideration is that the Müller and Schumann subjects required about the same number of repetitions as did Ebbinghaus although the rate of repetition was only about half as fast. It may be added that Ebert and Meumann obtained closely similar results with the standard procedure when their subjects were still unpracticed (W = 15.41 for series of 12 members) although their rate of repetition was one syllable to every 5/6 of a second— almost as slow as ours.[1] A second consideration is that meaningless syllables cannot be intelligibly presented *to the ear* at a rate much faster than one per second. The writer believes that the rate of one syllable per second taxes the subject's auditory apprehension as much as a rate 5/4 as fast taxes his visual apprehension. This opinion needs an exact experimental verification for which we have never had the proper apparatus, but it is more than a conjecture. Further discussion of the reasons for the difference between our results and those of Ebbinghaus and Müller will be postponed to the last section of this chapter. On the basis of the facts now before us we may conclude, first, that slow rate of presentation is an important factor in explaining the results characteristic of our reconstruction method; second, that slow presentation is not, taken alone, the all-explaining and crucial peculiarity of this method, and third, that our experiments with the method of complete memorising, like our experiments by the reconstruction method, lack some circumstance which raises

[1] See Ebert and Meumann, *op. cit.*, p. 43 and p. 75.

the number of necessary repetitions in the Ebbinghaus-Müller method.

Before passing to two more conclusions which may be drawn from the tables, one may remark that the figures do not help one to decide whether the slow presentation of the series-members or the allowing of slow recitation is the more important factor in reducing the number of repetitions. From the work of G., represented in Table XIII, work done at the subject's highest practice-level, it would appear that this subject could learn the series which were presented rapidly but might be recited slowly with a rather smaller number of repetitions than the series which were presented slowly but had to be recited rapidly. In passing from the reconstruction method to the method of complete memorising, the subject seemed to have more difficulty in adjusting herself to the necessity of rapid recall than to the necessity of rapid apprehension and grouping. However, the number of series in each set is too few and the existing results too inconsistent to warrant any positive conclusion. The trend of Table XV is in the opposite direction to that of Table XIII. This table represents the work of beginners, and the work of G. after some lapse of practice. From this table, it would seem that the number of repetitions necessary for learning is rather more affected by difference in the rate of presentation than by difference in the rate of recitation. This showing is not surprising for most of the repetitions contained much more presentation than recitation. A characteristic of the method of complete memorising, at least in our own experiments, is that the subject, who has failed repeatedly upon some one of the earlier sequences of a series, should often rather suddenly recite the series from beginning to end. The degree to which the repetitions were made up of presentation of course appears clearly in the original records but it is also implied by the figures in the last column of the table. The mean time in every case in which a *fixed* rate of recitation differed from the rate of presentation is obviously made up mainly of presentation-intervals.[1] On the whole, as regards the relative value

[1] How the effect of one set of intervals may dominate over the other may be seen from the following illustration: Suppose that under the conditions of these

of slow presentation and leisurely recall in reducing the number of repetitions necessary for memorising, the data represented in Table XV are too complicated to warrant a very definite conclusion. One can see only that the advantage of allowing leisurely recall is not great enough to outweigh the advantage of allowing leisurely apprehension *plus* the advantage of traversing the major portion of the series at a slow rate. But as regards economy of time—a saving which is here only an incidental consideration—it is clear that the allowing of leisurely recall is a positive advantage whereas slow presentation is not. Table XV shows that increasing the intervals at which the syllables must be or might be recited reduced the total time required for learning the series, whereas inceasing the intervals at which the syllables were presented increased this total time.[120]

The fifth and sixth conclusions to be drawn from the results of the twelfth group of experiments are incidental—that is to say, they do not bear directly upon any of the questions formulated on pages 173-176.

5. *Reducing the rate at which the members of a series are repeated is no royal road to quick memorising in spite of the saving in the number of repetitions and presumably in energy.* For, as we have just seen, *reducing the rate at which the syllables of a series are for the most part repeated, does not reduce the number of repetitions necessary for learning in anything like so great a proportion as it increases the time spent upon each repetition.* If one examines in Tables XIII and XV, the cases in which the rates of presentation and recitation were the same, one sees that quintupling or quadrupling the repetition-intervals does not by any manner of means reduce the number of necessary repeti-

experiments a series of 18 syllables is presented at the rate of one syllable to a second and recited at the rate of one syllable to every four seconds. Then if the first four syllables were recited and the last 14 presented, the time spent in the repetition would be $\overline{(3 \times 4 + 6 + 13 \times 1)} = 31$ seconds. But if the first 14 syllables were recited and the last four presented the time would be $\overline{(13 \times 4 + 6 + 3 \times 1)} = 61$ seconds.

[120] Since the presentation-intervals greatly predominate over the recitation-intervals, the lengthening of the presentation-intervals must have reduced the number of necessary repetitions *very much* more than the lengthening of the recitation-intervals reduced it if the total learning-time had been shortened.

tions to a fifth or a fourth of the number necessary at the more rapid rate. Moreover, if one examines the sixth and the ninth columns of Table XV, one sees that, except in the cases where the recitation-intervals were greater than the presentation-intervals, the average number of repetitions required at the slower rate of repetition is always a larger fraction of the average number required at the faster rate than the mean time spent upon the more rapid repetition is of the mean time spent upon the slower repetition. The fact that rapid repetition saves time in learning is not a new discovery[1] but it is nicely illustrated by these experiments. These particular experiments do not touch the question of the relative tenacity of associations formed by slow and by rapid repetition.

6. In general *doubling the series-length* in the experiment of the first two subgroups (Table XIII) *did not double the number of repetitions necessary for memorising.* With G., however, in all the six procedures save one, the number of repetitions necessary for memorising series of 81 members is at least approximately double the number necessary for learning series of 41 members. In four out of the six cases it is more than double. In the one procedure in which it is less than double the syllables were presented slowly but had to be recited rapidly. With this procedure, the subject certainly paid more than normal attention to the learning of the series of 81 members. Other anomalies exist in G.'s work, but they are probably due to the small number of series in each set. In the case of the beginners the increase of difficulty with series-length is really rather less in learning nonsense-syllables by either our standard or our prompting method of complete memorising than it is in learning syllables or colors by the reconstruction method. In the relatively small increase of difficulty with series-length we have another marked difference between our results with the method of complete memorising and those of Ebbinghaus. (See page 88.)

[1] See Ebbinghaus, *Grundzüge*, pp. 671–673; and Ephrussi, *op. cit.*, p. 183, squ. Upon the relative advantage of slow and rapid repetition, cf. also Bergström, *op. cit.*

B. Combination and Interpretation of Results.

In his *Grundzüge* Professor Ebbinghaus gives a concise and masterly exposition of the different methods used in memory investigation. At the end of this exposition stands a passage which may be freely translated as follows: "One has no right at all to presuppose that the investigation of the same problem by means of the different methods will furnish exactly the same results. To be sure, the law which operates under any given set of conditions is always objectively the same, but the conditions which are involved, *ipso facto*, in the application of the different methods are never the same. Even if all the external circumstances are entirely parallel, yet the aim of the subjects and with it their whole mental attitude will be different. It will vary, for example, according to whether they may have so to impress something on themselves as merely to recognize it afterwards or as they may have so to impress it as to be able to reproduce it actively. It will vary according to whether they must memorise the given matter as a whole or only the members which pair off with certain others; and it will vary according to whether they must retain what they have learned for a considerable time or only for the moment."[1]

As stated in the passage just quoted, different methods create different situations. The studies reported in this chapter are attempts to analyse the situation created by the reconstruction method, especially in comparison with the situation created by the method of complete memorising. The reconstruction method is left out of account by Ebbinghaus. Yet grossly rough as this method is, it deserves study because the memorising of series of concrete impressions as such cannot possibly be studied by any other.

The preceding pages have many times insisted on the peculiarity of the results obtained by the reconstruction method. Here the briefest summary will suffice. Unpractised subjects can memorise series of 12 and of 18 members with a number of repetitions which is surprisingly small in comparison with the number required by the method of complete memorising and

[1] *Grundzüge*, pp. 648–649.

especially in comparison with the number required by the special procedure of Ebbinghaus and of Müller. With our method, moreover, practiced subjects can learn series of 31 and 41 and even, when time permits, of 61 and of 81 members with a number of repetitions which approximates toward the number required for the smaller series. The number of sequences which can invariably be learned with a single presentation is not remarkable, but the number which a practiced subject can reproduce after a second presentation is astonishing. How, then, is the peculiar situation created by the reconstruction method related to these results? The problem is twofold: Why under the conditions of the reconstruction method is the number of repetitions required for memorising so small, and why with practice does series-length make so little difference? The first phase of the problem will be discussed first.

I. If the writer were required to sum up the peculiarities of the reconstruction method in one adjective the word chosen would be *easy-going*. *In the first place the required kind of recall seems easy;* therefore, the subject approaches his task in a relatively calm frame of mind,—an objective frame of mind in which he does not ask himself feverishly 'How soon will I be able to do this?' but asks himself coolly "What, then, is the exact nature of these impressions of which I am asked to learn the order?" The theorist who approaches them atter for the first time usually says, off-hand, that "the reconstruction method is easy because the subject does not have to learn the series-members but only their order." This statement is literally true but not chiefly in the sense given to it by the tyro in memorising. The reconstruction method is easier because the subject does not *have to* learn the series-members—that is, because he is not *asked* to learn them—but not because he *does not* learn them. Suppose that one is asked for the first time to learn the order of the presidents of the United States. Will one proceed in a different way than if one were asked to learn the names of the presidents? Will not the natural procedure in both cases be to learn the names in order? The first requirement, however, seems easier than the second; one is much less

afraid, and with reason, of being panic-stricken—'phased'—at the moment when recall is demanded. Proper names which have a certain arbitrariness and cannot be recalled by any process of logical memory, have sometimes a maddening fashion of slipping just beyond one's reach when most wanted, behavior which is probably due to the reciprocal inhibition of associations which run out from the ideas which ought to bring them up. If one is asked, 'What did David say in his haste?' or 'What did Portia say about mercy?' one answers with mechanical glibness 'All men are liars' or "The quality of mercy is not strained; it falleth like the gentle dew from Heaven;" but if one is asked '*Who* said in his haste, All men are liars?' or '*Who* said, The quality of mercy is not strained?' though one may answer promptly, 'David' or Portia,' yet the reproduction-reaction time will be a little longer, and one may be conscious of the swift mediation of other images—perhaps of an open Psalter or of a mediæval court-room. One may even detect and suppress a conflicting association with the mercy-quotation; a New Testament scene or one or more of the Beatitudes may flash through one's mind, even when one seems to others scarcely to hesitate in giving the right answer. Now when proper names or syllables, which are still more senseless than proper names, are learned in order, no other association is likely to conflict with that which runs from the series-member to the idea of its number or place.[1] On the other hand, there are apt to be a number of conflicting associations with the association which runs from the number or place-on-the-list idea to the name or syllable, and even with the association with runs from one name or syllable to the next. For example, when one wishes to recall the name of the president who succeeded Andrew Jackson one's 'mind' may run feverishly about among the details of that gentleman's personal history or the actual consequences of his dictum 'To the

[1] Of course, this will not be true if the names and syllables figure in different series which one has occasion to memorise. Witness the confusion of the average American visitor to Berlin in regard to the departed members of that royal line in which an elector of Brandenburg became a king of Prussia, and a king of Prussia an emperor of Germany, so that two new sets of numbers have been introduced.

victors belong the spoils' and may refuse—at least for the moment—to proceed along the straight line of the presidents.[1]

In brief, the point which the writer wishes to make is this: One does one's work in about the same way whether one is asked to learn the order of series-members or to learn series-members in order. Even if one set out to learn simply the order, one could not altogether escape learning the content of the series-members, any more than in learning series-members, always presented in the same order, one could altogether escape learning that order. The experimental results reported on pages 118 and 155 and the corresponding introspective observations have made amply clear the fact that in learning by the reconstruction method the subjects learned the content of the series-members either in order to learn the order or in learning the order. Nevertheless, *accidents are much more likely to occur in the recall of meaningless series-members than in the recall of their order.* The subject has had disagreeable experiences in reciting names, paradigms, and other matter which must be memorised mechanically, and is thrown into a state of trepidation by the demand that he should 'learn nonsense-syllables,' whereas learning the 'mere order' of colors, smells, and syllables seems to him relatively easy. Now when one is frightened in learning or in reciting, one learns or recites poorly because one's attention keeps jerking back from the material to be learned or reproduced to the idea of one self as succeeding or failing and to one's own organic sensations. The emotional disturbance, taken together with some genuine danger of a 'block' in the recall of certain syllables, explains the fact that it is really, though slightly, easier to reconstruct a series of nonsense-syllables than to reproduce it, a fact which has been

[1] The writer believes that divergence and conflict of associations is the chief explanation of the difficulty of remembering a foreign equivalent for an English word as compared with the difficulty of remembering the English equivalent for a foreign word. If one is asked 'What does *Schnur* mean' one answers promptly 'string!' but if one is asked 'What is the German word for *string*' one is likely to think the English words *cord*, *thread*, and so on, or to see parti-colored visions of strings, before one gets to *Schnur*. Some uncalled-for verbal or concrete image associate may even lead one off on a wrong track. Thus one may find oneself thinking *string—draw-string*, and replying 'Draht!'

pretty satisfactorily demonstrated by the experiments reported on page 155. Nevertheless, the fact that the series-members are given again and do not have to be recalled bodily in the reconstruction method is not sufficient to explain the difference between this method and the method of complete memorising. In the very group of experiments last mentioned, which show that reconstruction is a trifle easier than reproduction, the subjects learned to reproduce the series (which were presented in exactly the same way as in the reconstruction method) with a far smaller number of repetitions than are required in the method of complete memorising.

In this connection should be noted a point which is important though rather difficult to evaluate: The criss-cross associations between members of the series which do not stand next to each other are fostered much more by attention to the order of series-members than by attention to the members themselves.

The second respect in which the reconstruction method is easy-going lies in the fact that complete presentations of the series alternate with opportunities to test one's knowledge of the series-order as a whole—the opportunities which are called, for brevity, tests. The interpolation of tests has four consequences: (1) The subject impresses upon himself both the sequences and positions which he has learned and also certain mistaken notions of order. (2) The strain upon attention involved in the presentations is relieved; periods of relatively slack attention can occur in the process of learning without doing any harm. (3) The subject need not seek to test himself and to impress the series-sequences on himself at the same time; he can give his whole attention alternately to one process and to the other. (4) The presentations are distributed over a wider time interval. Thus, series learned by the reconstruction method have to a certain extent the advantage of 'distributed repetitions.' The learning process comes under Jost's law that a new repetition of a series has more effect on a long standing association than on a relatively fresh association. In the belief of the writer this law has a physiological basis. This matter will be taken up again. Here it should be noted that the experiments reported on pages 162, 165 and 170 have shown that the advantages accruing

from the mere multiplication of tests,—either through the testing-process or through the interpolation of intervals between presentations,—is relatively of minor importance.

The third respect in which the reconstruction method is easy-going lies in the fact that not merely long time but unlimited time is allowed for recall. The last group of experiments reported (see pages 175 and 188) has shown that this circumstance is of very great importance indeed. 'Leisurely recall' contributes greatly to the emotional equilibrium of the subject. Whether or not it contributes more than 'leisurely apprehension,' this study fails to tell us.

The fourth respect in which the reconstruction method is easy-going lies in the fact that the members are slowly presented. The slow rate of presentation has the following consequences: (1) The series-members are satisfactorily apprehended so that the subject is not confused as to their exact nature, except where real difficulties in sensible discrimination come into play. (2) The subject is not agitated by the effort to apprehend quickly. (3) The attention of the subject is not so taken up in the effort to apprehend the separate members rapidly that no attention is left over for noting order. (4) During the exposure of a series-member and the interval following it, the subject has time to lay stress upon the sequence which this member completes. He thus (3 and 4) may grasp the series-members in pairs instead of in isolation. A series becomes to him *a—b*, *b—c*, *c—d*, *d—e*, and so on instead of remaining *a*, *b*, *c*, *d*, *e*. (5) If the subject can shift his attention rapidly he is able to clinch more sequences than the last during the interval between exposures. (6) He has time to couple each series-member with the notion of its number in the series. He may not and usually does not consciously clinch each series-member both with the preceding member and with the absolute number in the series. Nevertheless, he has full time for the kind of counting, often non-verbal, which, with or without the formation of firm criss-cross associations, is involved in grouping. (7) The subject has time to couple the series-members with images of places on the table before him so that the place ideas become distinctly spatial. (8) He has time deliberately to make auxiliary associa-

tions. (9) Auxiliary associations not deliberately made have time to come into play. (10) A relatively great length of time supervenes between the earlier and later sequences of the series and this lessens the inhibitive action of one part upon the other. This very important point will be taken up again in a moment. (11) The time consumed in each presentation of the whole series is lengthened so that the interval between the moment when any one sequence—say, *c*—*d*—is presented in any repetition, and the moment when it comes around in the next repetition is also lengthened. Thus, slowly presented series have, after a fashion, the advantage of distributed repetitions, whatever this advantage may be.

Against these consequences of slow presentation, which are all advantageous in the sense that they tend to decrease the number of repetitions necessary, must be added two disadvantageous consequences: (12) In the case of the smells and colors, the long intervals which elapse between the series-members increase the difficulty of sensible discrimination. (13) The demands upon the subject are not strenuous enough to keep attention steady. This fact was shown by experiments described on pages 150 and 153.

All the consequences which arise from presenting nonsense-syllables slowly by the reconstruction method arise from presenting them slowly in the method of complete memorising excepting only the seventh of those named above. Slow presentation greatly reduces the number of repetitions necessary in the method of complete memorising (see pages 188-191). We may, therefore, infer that slow presentation is an important factor in making the number required by the reconstruction method absolutely small. Nevertheless, slow presentation in the case of the reconstruction method does not in itself suffice to explain the difference between the results of the two methods. For when syllables are repeated in the method of complete memorising at exactly the same rate as they are presented in the reconstruction method, yet still the number of repetitions required for learning remains rather greater than the number required for learning syllable-series by the reconstruction method proper. Moreover, it remains rather greater than the number required

for learning series which are presented in the same way and at the same rate as in the reconstruction method, but which are reproduced in writing after each presentation.

In brief, the first of the two problems at issue in this chapter—namely, the reason for the fewness of the repetitions required by the reconstruction method—may, in the opinion of the writer, be solved somewhat as follows: *The leasurely recall and the slow rate of presentation in the reconstruction method largely explains the difference between the number of repetitions required with this method and the number required with the procedure of Ebbinghaus and of Muller and Schumann. Leasurely recall involves a certain amount of composure on the part of the subject. Slow presentation involves complete apprehension of the series-members, a certain amount of emotional composure, and the slow traversing of the sequences. This slow traversing of the sequences probably involves an advantage of purely physiological origin and certainly fosters the development of a certain learning-technique on the part of the subjects.* (These last two points will be discussed in a moment.) Either the explanation by leasurely recall or the explanation by slow presentation leaves unexplained a residuum of difference between our reconstruction method results and the results of the Ebbinghaus and Muller procedures. For in our own procedure with the method of complete memorising, neither when the series were presented as slowly as in the reconstruction-method nor when unlimited time was allowed for recall, was the number of repetitions required as small as in the reconstruction method. It may be that the two explanations taken together very nearly account for the difference under discussion.[1] It seems probable, however, that the difference is explained in some slight degree by the multiplication of tests in the case of the reconstruction method and by the fact that the subject is required to reproduce only the order of the series-members. *The chief, not the exclusive, advantage in interpolating a test after each presentation of the series lies in the fact that high-level and undivided attention*

[1] In none of our experiments with the method of complete memorising was it the case both that series were presented quite as slowly as in the reconstruction method and that unlimited time was allowed for reproduction.

is secured during the tests themselves. The chief (not the only) advantage in 'the presence of the links' lies in the fact that the subject is not perturbed by the demands upon him.

Closely connected with the first problem of the chapter, though not a part of it, is the question why a smaller number of repetitions is required in our complete-memorising procedure, even when series are presented and recited rapidly, than the number which is required in the Ebbinghaus and the Müller-Schumann procedures. The difference cannot be due to difference in rate. (See p. 190.) Neither is it due to the fact that English nonsense-syllables are easier to memorise than German. It is true that among our own English normal series more words occur than are found among the German series of Müller and Schumann, but this aid to the learner is fully offset by the fact that English syllables which are spelled alike are not always pronounced alike and *vice versa*. It cannot be that the number of repetitions is smaller in our procedure because auditory, *viva voce*, presentation is more impressive than visual.[1] To the writer, it seems probable that the number is smaller on account of the technique acquired by the subjects in learning those series which were slowly presented *pari passu* with the series which were rapidly presented.

II. Slow presentation is, in the belief of the writer, the key to the second problem at issue in this chapter: the question why series-length makes relatively little difference in the number of repetitions required for memorising by the reconstruction method. *Slow presentation has two great advantages. The first lies in the fact that when a series is slowly presented the mutual interference of the different association is lessened.* This advantage is a plain fact of introspection. To explain it the writer has worked out a theory made up, crazy-quilt fashion, out of shreds and patches of other people's theories and observations.[2] This speculation involves the following suppositions:

1. In order that an association may be even relatively permanent, some process of consolidation or 'setting' must take

[1] Cf. Pohlmann, *op. cit.*, p. 168.

[2] The theory is so eclectic that references cannot be given without space-consuming discussion.

place.[1] This process consists in some modification of the nerve-fibers connecting two cortical areas.

2. The consolidation process requires time and cortical energy and will not take place if the persistence of the processes which directly conditioned the occurrence of the associated ideas in consciousness is too quickly interrupted. This statement needs to be amplified by a discussion of three points, namely, time as a factor in the consolidation-process, cortical energy, and persistence and its interruption.

First, the consolidation-process, as a gradual one, differs from the nerve-path process which forms the association when two cortical areas function together or in close succession; one might say, metaphorically, that the former differs from the latter as the 'setting' of a jelly differs from its moulding. The more consolidation has taken place, the more an association

[1] The writer has meant (and means with unblushing determination) to use the word *association* to stand interchangeably for the 'connection' of ideas in virtue of which one 'tends to suggest' another and for the cortical modification in virtue of which an excitation tends to run over from one cortical area to another. The writer eschews the use of the term *association* to stand for the process of reproduction or for the actual arousing or 'touching off' of excitation in one cortical area by excitation in another. It seems, however, mere word-wasting pedantry to insist on distinguishing at every turn by separate expressions the so-called association of ideas and the cortical modification which conditions it. We know of the cortical modification only through the touching-off process which it conditions and this we know only through its psychical index, the 'suggestion' of one idea 'by' another. Nevertheless, the cortical modification or 'trace' is the only tie which persists. Ideas in consciousness are not connected with ideas out of consciousness. Ideas cannot exist out of consciousness. The more or less orderly sequence of ideas is experienced and introspectively observed; their connection—unless connection means merely the frequent sequence of particular ideas—is not experienced. Association 'between' ideas cannot inhibit one another; *between* is meaningless with reference to something and nothing, that is, to the idea in consciousness and the idea not recalled and perhaps never to be recalled. *The association of ideas is* a mere short-hand expression for a neural tendency based on a cortical modification. Therefore, it seems absurd, instead of saying 'The association *knife Messer* inhibits the association *knife couteau*' to say 'The tendency of the cortical excitation which conditions the verbal image *knife* to arouse the cortical excitation which conditions the verbal image *Messer* inhibits the tendency of the former to arouse the cortical excitation which conditions the verbal image *couteau*.' (Cf. Binet, *L'Associations des Idées*, pp. 6–7.) In this matter, there is no danger of confusing one's physiology and psychology unduly because there is nothing on the psychical side to answer to association in the sense of actual connection.

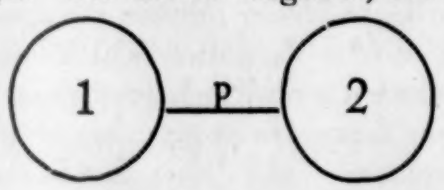
is strengthened by the repetition of the process which forms it. Hence, Jost's first law, and the advantage of distributed repetitions.[1] By the strengthening of an association is meant the insuring of its functioning, and, other things being equal, the shortening of its functioning time. An association is strengthened first by consolidation; second, by every repetition of the process which forms it, e. g., by every *presentation* of a syllable-sequence; and third, by every actual functioning,—e. g., by every *recitation* of this syllable-sequence.

Second, the notion of cerebral energy here employed is almost as vague as the notion of modification in the association-fibers. It may mean reinforcement by the 'association centers' or ample blood supply or both. Whatever energy means, it is here assumed that the draughting of it to one piece of work tends to take it away from another.

Third, by persistence the writer means the continuance, after an idea has vanished from conciousness, of the cortical excitation which at sufficient intensity brings about the occurrence of this idea. During the period of continuance, the excitation, if not set up afresh by transmission from some other nerve-center, is rapidly subsiding, but this subsidence or ringing off (*Abklingen*) is characterised by little rises or swells which may bring about the recurrence of the idea. Persistence and consolidation are two different processes. The former may be thought of as a cortical-center process; the latter as a nerve-path process. The former may directly bring about the recurrence of a recent idea; the latter paves the way for the recurrence of an idea perhaps no longer recent. Nevertheless, although the two processes are not the same, a certain amount of persistence of excitation in the cortical areas concerned, is a prerequisite to consolidation.[2] Excitations in only a limited

[1] See Jost, *op. cit.*, p. 472. See also Ebbinghaus, *Grundzüge*, pp. 657–660.

[2]



This figure may serve to represent two cortical sensory areas with an interconnecting path. Excitations in 1 and 2 condition percepts or images. (The writer assumes that the excitation which conditions a percept and that which

number of areas can persist at any one time for persist ence requires cortical energy, and the amount of energy available at any one time is limited, although it seems to vary in different individuals. The formation of fresh associations also requires cortical energy.

3. There is not in any short space of time—say, in the time consumed in rapidly repeating a series of forty syllables—enough cerebral energy both to allow a large number of excitations to persist and thus to furnish the initial prerequisite for

conditions the corresponding image take place in the same cortical area.) The continuance of the excitations is *persistence*. The modification somehow produced in the nerve-path *p* when the areas 1 and 2 function at about the same time is an *association*. The modifying process is the *forming* of the association; the 'setting' of the modification is the *consolidation* of the association; the transmission of excitation from 1 to 2 along the path *p* is the *functioning* of the association. Every repetition (within certain limits) of the condition which led to the first forming of the association and every repetition of its actual functioning *strengthen* the association—that is to say, they increase its readiness to function.

The writer does not wish to postulate in this speculation any particular theory of the interconnection between the 'knots of neurones' in the cortex or of the functional relation between the nerve-cell-body and its processes. That there are areas in the cortex which represent, very roughly indeed, particular contents of consciousness and that excitation is transmitted from one area to another over some material path or paths is scarcely to be called a mere theory.

The writer has attempted to divest the *Perserserationstendenz* of Müller and Pilzecker of a Herbartian guise which it does not seem necessary for it to wear. These writers ascribe to the idea (*Vorstellung*) a quickly diminishing tendency to come back into consciousness of its own accord and say that an idea attentively, repeatedly, and recently experienced will often possess such a strong persistence-tendency that it will push its way into consciousness at any moment when consciousness is not besieged by other 'factors.' Is not this merely the figurative language of brevity? If one speaks, for the sake of brevity, of ideas as persisting or as inhibiting one another, does it necessarily mean that one soberly hypostatises the idea? Ebbinghaus's two objections to the persistence-doctrine are first, that the physiological conditions assumed have no parallel, and second, that all ideas do not persist. What then of the conditions of retinal after-images? The retina and the cerebral cortex are surely near akin in origin and in structure. And what of retinal rivalry? What also of the differences in individual liability to after-images? There is, surely some introspective and experimental evidence for persistence. It may be possible to interpret all such data by chains of subliminal associations, but this explanation often seems to go further afield than the supposition of persistence. Cf. Müller and Pilzecker, *op. cit.*, pp. 58–78; Aschaffenbrug, *Experimentelle Studien über Assoziationen*, Kräplin's Psychologische Arbeiten, i, pp. 55, 61 and 66; Wreschner, *Die Reproduction und Assoziation von Vorstellungen*, Zeitschrift f. Psych. und Phys. der Sinnesorgane, Ergänzungsband 3, pp. 237–258; and Ebbinghaus *Grundzüge*, pp. 691-692.

the consolidation of a large number of associations, and over and above this to form a large number of new associati ns. Therefore, when a long series is rapidly presented for the first time, the persistence of the earlier members blocks the formation of associations between the later members. Furthermore, the actual appearance and the persistence of the later members tend to prevent the consolidation of the associations already formed. The association $\widehat{p\,q}$ when formed and 'setting' dissolves $\widehat{c\,d}$, and $\widehat{c\,d}$, when reformed and setting, dissolves $\widehat{p\,q}$. As Ebbinghaus says: "Many persons can never in any reasonable length of time achieve a perfectly correct recitation of the longer series of nonsense-syllables. Some parts are continually thrown into confusion by others, ... The readings which follow the first readings of a series often bring about only a slight increase in the subject's power to reproduce it. The mutual disturbance of the series-members by one another, which is distinctly manifest to immediate consciousness, brings the process of learning to a standstill, and only when the whole series has become somewhat more familiar through several readings does a further and marked increase in the number of retained elements take place."

4. When on the other hand a series is slowly presented—even when the subject is scarcely conscious of having free time but seems to busy himself with each sequence as it comes—the mutual interference of the incipient associations is much diminished because energy is not draughted so rapidly in different directions. Hence when series are slowly enough presented their length makes relatively little difference. This is the point which of all others the writer desires to make. However vague and rash the physiological speculation of the last few paragraphs may be, yet no very skilled introspection is required to discover that associations dislodge one another when a long series is rapidly presented, and may, as it were, be held peaceably side by side when a like series is slowly presented.

5. Series, if short, are learned in a shorter time when rapidly presented than when slowly presented, but this fact does not disprove the theory just advanced for, in this case, the great *persistence* of all the series-members may compensate for the

defective consolidation of the associations. This supposition requires amplification. Every attentive repetition of a series, of course, strengthens the associations involved. But all repetitions of a series do not strengthen the associations to the same extent. It is obvious that a slow repetition accomplishes more *absolutely* than a rapid repetition, since fewer slow repetitions are required to bring all the associations to that particular readiness to function which we call the mastery of the series. This fact has just been explained by the supposition of a consolidation-process which requires time. Nevertheless, a rapid repetition accomplishes more in proportion to the time expended on it than a slow repetition, for halving the time allowed for each repetition of the series does not double the number of repetitions necessary. Rapid repetition must, therefore, involve some advantage which offsets the interruption of the consolidation-process. If it did not, halving the time would *at least* double the number of necessary repetitions; and indeed if the consolidation-processes are cumulative, halving the time might more than double the number of repetitions. Now rapid repetition may be supposed greatly to increase the persistence of the series-members because the excitations which condition their appearance in consciousness are renewed before they have had time to subside so that the prolonging effect is cumulative. Furthermore, a weak association may be supposed to be sufficient to raise a process which is still subsiding to such a level (*Niveau*) that the corresponding idea emerges in consciousness. Therefore, after a number of rapid repetitions of a rather short series, one finds the series suddenly resounding in one's ears or rolling off before one's eyes from start to finish.

6. The length of the series which can be learned by rapid repetition is sharply limited except in certain cases in which a subject—such as G.—has had long practice in memorising and has acquired a deft technique. In ordinary cases, the subject cannot learn a long series if rapidly repeated, with any reasonable number of repetitions, because its members cannot all persist at once, and the incipient associations between them dissolve one another. On the other hand, an association once

fairly consolidated draughts off no energy until it functions. Hence, if there were no limits to the amount of time which can be spent in learning series there would be no limit to the length of the series which the subject could learn with slow repetition. It should not be forgotten that the lengthening of the series in itself gives to the individual sequences the advantage of distributed repetitions. Of course, the rate of repetition need not be made slower and slower as the length of the series is increased. Each interval (for example, that between *c* and *d*) need be long enough only to allow the taking place of a certain degree of consolidation in the association just formed ($\widehat{b\ c}$); if the interval is made too long, no association will be formed between the series-members which bound it (*c* and *d*).

Before this discussion of consolidation *versus* persistence is closed, two more points should be expressly noted. In the first place, the phenomena of memorising with quick repetition seem intermediate between the phenomena of memorising with slow repetition and the phenomena of the memory-span. The width of the memory-span depends on attention-range and persistence; facility in memorising with rapid repetition probably depends largely on persistence; facility in memorising by slow repetition cannot depend on persistence at all, but must depend on the readiness of the cortex (association-fibers) to receive and to consolidate the modifications which constitute associations.

In the second place it should be noted that further experiment may prove that series learned with rapid repetition are as well remembered for hours as series learned by repetition as slow as the presentation of our reconstruction method. If this should prove to be the case, then the foregoing speculation falls wholly to the ground.

It will be remembered that *two important advantages were attributed* (on page 202) *to slow repetition.* The first—namely, the lessening of the conflict between incipient associations—has just been discussed. *The second is the development of a technique which can scarcely be gained under either the sensory or the emotional conditions of rapid repetition*, although when developed it may be used under those conditions. Slow presentation is

the secret of the astounding results of practice in the reconstruction method. The nature of the technique acquired has already been so fully described that it need scarcely be sketched here. It does *not* consist of mnemonic devices. In the case of all sorts of material, it consists in part of keenness of apprehension, that is, of precision both in apprehending the individual series-members and in apprehending sequences. In the case of meaningless material it consists largely in the practice of grouping. In the case of non-verbal material it consists in the differentiation and stereotyping of the imagery, so that each unit in the material has some one mental counter all to itself. In G.'s technique a highly important factor was the system of spatial projection fostered by the peculiarities of the reconstruction method. Our experiments to test with other subjects the value of spatial associations have had a negative outcome, but these experiments were not extensive nor exact.

It may be urged that the same technique could in time be acquired with rapid repetition. Perhaps, if the time were long enough, but it must indeed be long. Many of us have had an experience which brings home the fact that exercises in apprehension are ineffective if too difficult. In our first few weeks in France or in Germany, we may have learned absolutely nothing from the rapid table-talk of the natives. We might as well not have sat at the table; as far as language-learning went, a solitary half-hour with our grammar would have been more profitable. Yet we learned much from the slow speech of benevolent foreigners, and having learned through it to recognize the foreign words, we finally learned much from the table-talk which at first passed utterly over our heads. In any case—whatever may be acquired through rapid repetition—the writer is convinced of two things, first that it was the technique acquired in learning with slower repetition which enabled her to learn series of 81 nonsense-syllables when presented as rapidly as one per second, and second, that it was mainly the technique acquired with the series which were slowly presented which enabled our unpracticed subjects to learn the rapidly presented series with a number of repetitions which was small as compared with the number required by Ebbinghaus and the Müller-Schumann subjects.

From a practical point of view, the conclusion of the whole matter is this: To learn a single short series of any kind in a short time, one should repeat it as rapidly as one can with complete apprehension, but to learn long series and *to learn to learn anything* one should repeat at a rate much slower than that which just allows the perfect apprehension of the material to be learned —perhaps, at a rate four or five times as slow as this maximum. If those who essay memory-training would enter the strait and thorny path by the proper wicket-gate, and would start with less extravagant expectations, they might not land in such numbers in the Slough of Despond. It is probable that practice is transferable only within very narrow limits. It is probable also that one's 'brute retentiveness' cannot be improved by training. Nevertheless, *it is certain that a very great difference can be made by training in what one can do with one's brute retentiveness along specific lines.*

APPENDIX.

PUBLISHD REEPORTS OF THE WORK OF THE WELLESLEY COLLEGE PSYCHOLOGY LABORATORY.

1893 *Statistical Study of Pseudochromæsthesia and of Mental Forms.* By M. W. Calkins. American Journal of Psychology.

1895 *Minor Studies from the Psychological Laboratory of Wellesley College.* American Journal of Psychology.

The Continued Story. By M. W. Learoyd and M. L. Taylor.

Synæsthesia. By M. W. Calkins.

1896 *Minor Studies from the Psychological Laboratory of Wellesley College.* American Journal of Psychology

The Dream Consciousness. By S. C. Weed, F. H. Hallam and others.

1898 *Short Studies in Memory and in Association from the Wellesley College Laboratory.* By M. W. Calkins. Psychological Review.

1900 *Wellesley College Psychological Studies: An Attempted Experiment in Psychological Aesthetics.* By M. W. Calkins with the assistance of H. Buttrick and M. W. Young. Psychological Review.

Minor Studies from the Psychological Laboratory of Wellesley College. American Journal of Psychology.

Studies of the Dream Consciousness. By G. A. Andrews.

1902 *The Perception of Sound Direction as a Conscious Process.* By E. A. McC. Gamble. Psychological Review.

1903 *Die reproducierte Vorstellung beim Wiedererkennen und Vergleichen.* By E. A. McGamble and M. W. Calkins. Zeitschrift für Psychologie und Physiologie der Sinnesorgane.

1905 *Attention and Thoracic Breathing.* By E. A. McG. Gamble. American Journal of Psychology.

1906 *The Effect of Music upon Thoracic Breathing.* By Eugenia Foster and E. A. McC. Gamble. American Journal of Psychology.

1908 *The Effect of Suggestion upon the Reproduction of Triangles and of Point Distances.* By J. C. Bell with the assistance of G. E. Hatch and L. T. Orr. American Journal of Psychology.